LAKE MACQUARIE CITY

Flooding event in the study area – July 2020 (Photo courtesy of a local resident)

DRAFT FLOOD STUDY FOR MORANS CREEK, STOCKTON CREEK, MULLARDS CREEK, CLACKS CREEK, MELALEUCA CREEK AND DORA CREEK

August 2024

PREPARED FOR LAKE MACQUARIE CITY COUNCIL BY ENGENY AUSTRALIA PTY LTD

DISCLAIMER

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CONTENTS

1. Introduction 1

 1.1 Assessment Limitations and Accuracy 1

2. Background 2

 2.1 Site Context 2

 2.2 Previous Flood Studies 4

  2.2.1 Dora Creek Flood Study – May 1986 4

  2.2.2 Dora Creek Floodplain Management Study Hydraulic Analysis of Subdivision Options – February 1991 5

  2.2.3 Lake Macquarie Flood Study 5

  2.2.4 Dora Creek: Floodplain Management Plan – June 1998 6

  2.2.5 Dora Creek Flood Study – May 2015 6

  2.2.6 Dora Creek Floodplain Risk Management Study and Plan – June 2015 7

  2.2.7 Mandalong Coal Mine Flood Study – Engeny, 2022 7

 2.3 Relevant Legislation & Guidelines 7

3. Available Data 8

 3.1 Rainfall Data 8

 3.2 Level and Flow Data 8

 3.3 Design IFD Data 11

 3.4 Topographic and Bathymetric Survey 11

 3.5 Structure Survey 12

  3.5.1 Bridges 12

  3.5.2 Culverts, Pits, and Pipes 12

 3.6 Flood Marks 13

 3.7 Resident Data Survey 13

4. Flood Assessment 14

 4.1 Hydrologic Modelling Methodology 14

  4.1.1 Modelled Events 14

  4.1.2 Critical Durations 14

  4.1.3 Model Overview 14

 4.2 Hydraulic Modelling Methodology 17

  4.2.1 Topography and Model Extent 17

  4.2.2 Grid Size and Time Step 17

  4.2.3 Model Parameters 17

  4.2.4 Downstream Tail Water Conditions 17

  4.2.5 Hydraulic Model Duration and Ensemble Selection 17

  4.2.6 Model Parameter Sensitivity 18

  4.2.7 Model Overview 18

5. Model Verification 21

 5.1 Rainfall Event Calibration 21

  5.1.1 Historical Event Summary 21

  5.1.2 1989 Event 22

  5.1.3 June 2007 Event 23

  5.1.4 2015 Event 25

5.1.5 2022 Event 26
5.2 Flood Frequency Analysis (FFA) 28
5.3 Verified Model Parameters 30
6. Design Event Modelling 31
6.1 1% AEP flood event 31
6.2 Climate Change Analysis 33
6.2.1 Climate Change 33
6.3 Sensitivity Analysis 39
6.3.1 Blockage of Pipes/ Bridges/ Culverts 39
6.3.2 Mannings Roughness 39
7. Consequences of Flooding on the community 43
7.1 Flood Hazard 43
7.2 Flood Function (Hydraulic Categorisation) 45
7.3 Flood Emergency Response Classification of Communities 47
7.3.1 Flood Islands 49
7.4 Consequences of Flooding on People 50
7.5 Flood Damages Assessment 52
7.5.1 Input Data and Damage Curves 52
7.5.2 Flood Damages Assessment 53
7.6 Flood Planning Area 56
8. Next Steps 58
9. References 59
10. Qualifications 60

Tables

Table 2.1: Catchment Details Utilised 4
Table 2.2: Peak Flow Estimates 5
Table 2.3: Final WBNM inputs – from 2012 Study 6
Table 2.4: FinAl WBNM inputs – WMA 2015 6
Table 2.5: Adopted Mannings n Values – Tuflow Model 7
Table 3.1: Available Rainfall Gauges 8
Table 3.2: Available Flow and Level Gauges 11
Table 3.3: Example Design Rainfall intensities (AEP) Applied to the Catchment (mm) 11
Table 3.4: Summary of Available Topographic and Bathymetric Survey Data 12
Table 3.5: Culvert Data 13
Table 3.6: Flood Marks 13
Table 4.1: Hydrologic Model Parameter Summary 15
Table 4.2: Hyraulic Model Parameters 18
Table 4.3: AEP Event Tailwater Conditions 19
Table 4.4: Calibration Events – Tailwater Conditions 19
Table 5.1: Calibrated Event Parameters 21
Table 5.2: Selected Rainfall Event Details 21
Table 5.3: FFA Peak Discharge Results Comparison 28
Table 5.4: Adopted Hydrologic Model Parameters for Design Events 30

Table 7.1: Flood Emergency Response Classifications ... 47
Table 7.2: Properties Subject to Ground Level Inundation ... 50
Table 7.3: Key Roads Inundated ... 52
Table 7.4: Residential Damage Disbenefits and Cost Summary ... 53
Table 7.5: Commercial/ Industrial and Public Building Damage Disbenefits And Costs Summary ... 54
Table 7.6: Other Disbenefits and Costs Summary ... 55

Figures

Figure 2.1: Study Area ... 2
Figure 2.2: Catchment Areas ... 3
Figure 3.1: Jigadee Creek at Avondale (Source WaterNSW) ... 9
Figure 3.2: MHL Morisset Gauge ... 10
Figure 3.3: MHL Kalang Road Gauge ... 10
Figure 4.1: Hydrologic Model Overview ... 16
Figure 4.2: Hydraulic Model Overview ... 20
Figure 5.1: MHL Mandalong and Martinsville Gauges Daily Rainfall (mm) ... 22
Figure 5.2: 1989 Event - Hydrology Model Results – Flow (m^3/s) ... 22
Figure 5.3: 1989 Event – Hydraulic Model Results – Level (mAHD) ... 23
Figure 5.4: 2007 Event – Hydrology Model Results – Flow (m^3/s) ... 24
Figure 5.5: 2007 Event – Hydraulic Model Results – Level (mAHD) ... 24
Figure 5.6: 2015 Event – Hydrology Model Results – Flow (m^3/s) ... 25
Figure 5.7: 2015 Event – Hydraulic Model Results (Best WBNM parameters not final calibration) – Level (mAHD) ... 26
Figure 5.8: 2015 Event – Final Calibration Hydraulic Model Results – Level (mAHD) ... 26
Figure 5.9: 2022 Event – Hydrology Model Results – Flow (m^3/s) ... 27
Figure 5.10: 2022 Event – Hydraulic Model Results – Level (mAHD) ... 27
Figure 5.11: FFA Results – Modelled vs Gumbel ... 29
Figure 5.12: FFA Results – Modelled vs Log Pearson III (Final Validation) ... 29
Figure 5.13: Yearly Peak Discharges (m^3/s) at Jigadee Gauge ... 30
Figure 6.1: Maximum Modelled Flood Depths – 1% AEP Event ... 32
Figure 6.2: Afflux –Sea Level Rise (0.5m) vs Baseline – 1% AEP Event (100 Year ARI) ... 34
Figure 6.3: Afflux –Sea Level Rise (0.9m) vs Baseline – 1% AEP Event (100 Year ARI) ... 35
Figure 6.4: Afflux –10% Rainfall Increase vs Baseline - 1% AEP event (100 Year ARI) ... 37
Figure 6.5: Afflux –20% Rainfall Increase vs Baseline - 1% AEP event (100 Year ARI) ... 38
Figure 6.6: Afflux – Blockage vs Baseline (no blockage) ... 40
Figure 6.7: Afflux –25% Mannings Rougness Increase vs Baseline - 1% AEP Event (100 Year ARI) ... 41
Figure 6.8: Afflux –25% Mannings Rougness Decrease vs Baseline - 1% AEP Event (100 Year ARI) ... 42
Figure 7.1: Combined Flood Hazard Curves (from ARR 2019). ... 43
Figure 7.2: Maximum Modelled Flood Hazard Categorisation ... 44
Figure 7.3: Flood Function Mapping ... 46
Figure 7.4:Flood Emergency Response Classification ... 48
Figure 7.5: Dora Creek West High Flood Island ... 49
Figure 7.6: Avondale Low Flood Island ... 49
Figure 7.7: Buildings and Key Roads Inundated for Design Flood Events ... 51
Figure 7.8: Contribution to AAD Breakdown ... 56
Figure 7.9: Flood Planning Area ... 57

Appendices

Appendix A: Questionairre Summary

Appendix B: Flood Mapping

Appendix C: Flood Mapping – Sensitivity Analysis

1. INTRODUCTION

Lake Macquarie City Council (Council) engaged Engeny Australia Pty Ltd (Engeny) to identify the flood risks throughout Morisset and surrounding areas. This involves completion of a combined flood study for Morans Creek, Stockton Creek, Mullards Creek, Clacks Creek, Melaleuca Creek and Dora Creek. The flood study will be used to inform the Morisset Place Strategy, which will guide future land use planning for the broader Morisset Area.

The primary objectives of the flood modelling are as follows:

- To define the flood behaviour of each creek and their tributaries.
- To produce information on flood levels, velocities and flows for a full range of flood events, under existing and future catchment and floodplain conditions for the study area. The study will take into consideration the impact and ramifications of climate change for the study and shall consider the following range of peak flood level and depth scenarios:
  - 50% AEP event (2 Year ARI)
  - 20% AEP event (5 Year ARI)
  - 10% AEP event (10 Year ARI)
  - 5% AEP event (20 Year ARI)
  - 2% AEP event (50 Year ARI)
  - 1% AEP event (100 Year ARI)
  - 0.5% AEP event (200 Year ARI)
  - 0.2% AEP event (500 Year ARI)
  - Probable Maximum Flood (PMF)
- To assess the impacts of sea level rise and increase in rainfall and runoff intensities due to climate change.
- To prepare hazard and hydraulic category mapping for each study area.
- To prepare Flood Emergency Response Planning Classification of Communities Mapping to assist SES.
- To assess impact of blockages on flood behaviour.
- To Identify appropriate land uses.
- To undertake a flood damages assessment.
- To prepare Flood Planning Constraint Category Mapping.

This study was initially undertake for the Stockton Creek, Morans Creek, Mullards Creek, Clacks Creek, Melaleuca Creek catchments. The detailed flood modelling undertaken for this study indicated a strong influence of Dora Creek flood levels on Stockton Creek, making the isolation of the Stockton Creek model difficult. In order to achieve more accurate flood model results and therefore more meaningful flood planning data, the model was extended to incorporate the Dora Creek catchment, however the study area remains unchanged.

1.1 Assessment Limitations and Accuracy

The accuracy of this assessment and all model results is reliant on the available data for model input and assumptions. The following overviews some key information that may limit the accuracy of this assessment:

- **Topographic and bathymetric data**: the Intergovernmental Committee on Surveying and Mapping's (ICSM) ELVIS LiDAR and the Office of Environment and Heritage (OEH) Lake Macquarie bathymetry have been utilised in the assessment. Flood extents, depths, and levels are limited to the accuracy of this data and may change if more detailed survey were attained.
- **Availability of key structure data:** culvert, pipe, and bridge specifications throughout the study area have been supplied by Council and supplemented by estimations where data is lacking. Estimations were based on site inspections and google earth imagery observations. A comparison against the previous Dora Creek Flood Study (WMA 2015) structure inputs was also completed to validate inputs.
- **Software updates**: this study has used the latest Watershed Bounded Network Model (WBNM) and TUFLOW modelling software available at the time of assessment. Future changes to the best practice modelling approaches and guidelines may lead to changes in predicted flooding impacts.

2. BACKGROUND

2.1 Site Context

The flood assessment has been completed for the Morans Creek, Stockton Creek, Mullards Creek, Clacks Creek, Melaleuca Creek and Dora Creek catchments, located in the local government area of Lake Macquarie, approximately 40 km southwest of Newcastle. These catchments have a combined area of approximately 220 km^2. However, the main study area is confined to Morisset and its surrounds, ranging from the southern boundary of downstream Dora Creek to approximately 3 km upstream of the M1 Highway near Mandalong. The study area is presented in Figure 2.1 below and expands approximately 14 km^2.

Stockton and Melaleuca Creek are tributaries of Dora Creek and have a combined catchment area of approximately 238 km^2. Dora Creek drains into the south-west edge of Lake Macquarie at Bonnells Bay. Lake Macquarie is tidally influenced and connects to the Pacific Ocean via the Swansea channel, approximately 12 km east of the Dora Creek outlet. Figure 2.2 provides an overview of the broader catchment area.

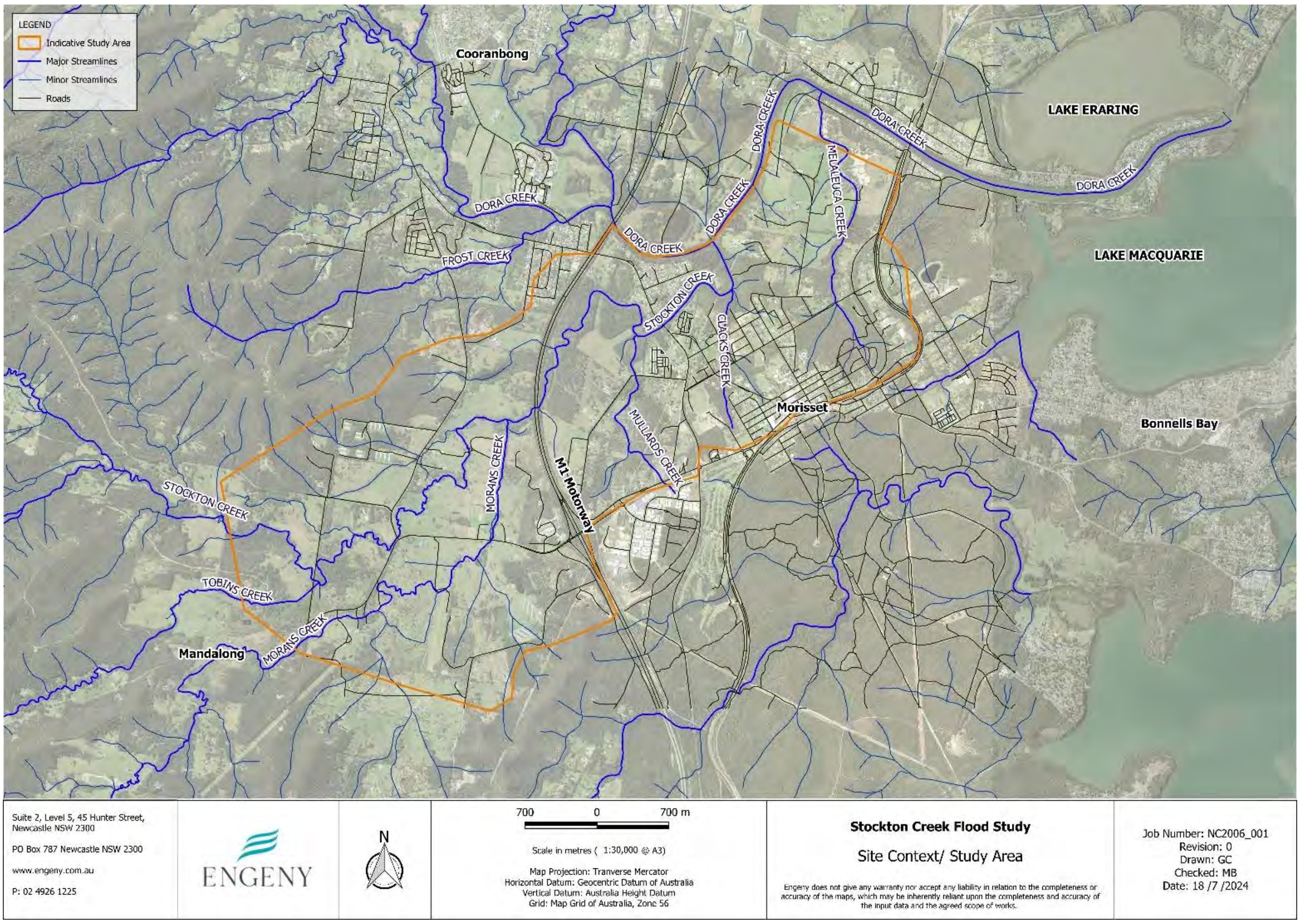

FIGURE 2.1: STUDY AREA

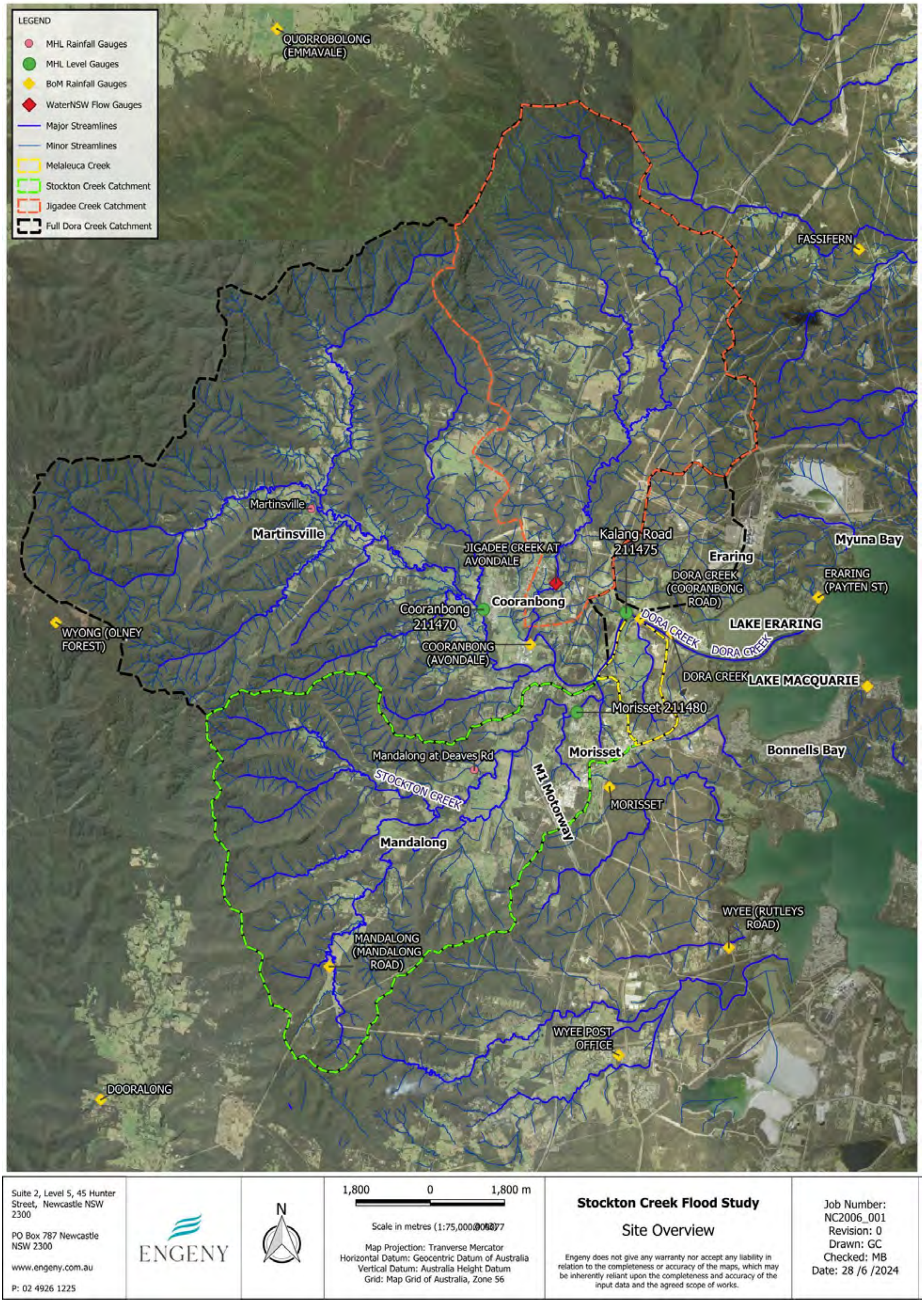

FIGURE 2.2: CATCHMENT AREAS

2.2 Previous Flood Studies

The NSW Flood Data Portal was accessed to gain an understanding of the previous flood studies that have been completed for the area. The flood studies that are applicable to the study area are summarised in this section. It should be noted that most of these studies investigate the full Dora Creek catchment, whereas this study focus' solely on the Stockton Creek (and Melaleuca Creek) sub catchments.

2.2.1 Dora Creek Flood Study – May 1986

The Public Works Department of NSW completed this study on behalf of Council, with the intent to "define the nature and extent of flood hazard under existing conditions". The study included Dora Creek and its two main tributaries, up to their tidal limits. Flood levels were determined below the Freemans Drive bridge on Dora Creek, downstream of the Newport Road Bridge on Jigadee Creek and downstream of the Cooranbong Road bridge on Stockton Creek.

Some of the key model parameters and modelling methodology that was utilised for this study are as follows:

- Bureau of Meteorology (BoM) derived rainfall intensity frequency duration curves for Newcastle were adopted for the design rainfall for the study. These were compared to the Australian Rainfall and Runoff (AR&R 77) estimation method, to confirm representativeness to the Dora Creek catchment.
- The Cordery-Webb design method, which was developed for rural catchments in eastern NSW, was used to produce design runoff hydrographs for the study.
  - Catchment details utilised are summarised below in Table 2.1.
  - An initial loss of between 18- 23 mm, depending on the storm duration, and a continuing loss of 2 mm/hr were assumed for the model.
  - Peak flow estimates from this method are summarised below in Table 2.2.
- A SAMOD mathematical hydraulic model was developed.
  - The SAMOD model was calibrated to historical data from the February 1981 flood event, through adjustment of Manning's roughness coefficients.
  - Model verification was not able to be undertaken due to lack of flood data.
  - The model was run with a water level in Lake Macquarie of 0.4 mAHD, which was 0.3 mAHD above the normal lake level (this was deemed to be the median lake level during flood events).
  - 5%, 2%, and 1% AEP events were modelled.

TABLE 2.1: CATCHMENT DETAILS UTILISED

Location	Catchment Area (km2)	Length (km)	Slope (m/m)	Time-area Diagram (C)	Catchment Storage factor (K)
Jigadee Creek	55	15.1	0.0045	4.7	3.1
Upper Dora Creek	60	17.5	0.0065	4.3	3.4
Stockton Creek	52	13.3	0.0040	4.7	2.9
Dora Creek (Railway)	196	25.0	0.0043	5.9	4.1

TABLE 2.2: PEAK FLOW ESTIMATES

Location	5% (1 in 20 year) AEP (m3/s)	5% (1 in 20 year) AEP (m3/s)	5% (1 in 20 year) AEP (m3/s)
Jigadee Creek	244	297	340
Upper Dora Creek	255	310	355
Stockton Creek	237	288	330
Dora Creek (Railway)	746	909	1044

2.2.2 Dora Creek Floodplain Management Study Hydraulic Analysis of Subdivision Options – February 1991

The Study was prepared for Council by the Public Works Department to assist with lower Dora Creek floodplain management. The flood study revised the Dora Creek Flood Study (1986) modelling; updating the design rainfall applied in the Cordey-Webb hydrologic model with AR&R 1987 data. Flood levels were evaluated in the 1D hydraulic modelling software MIKE-11 for the revised 1% AEP probability flows. An assumed downstream lake level of 0.6 mAHD was adopted in this study. The revised AR&R 1987 flows resulted in a general increase in predicted levels and velocities for the study area, compared to the 1989 Dora Creek model results.

2.2.3 Lake Macquarie Flood Study

The study was prepared for Council by Manly Hydraulics Laboratory (MHL), Department of Public Works and Services (DPWS), first in 1998 and subsequently updated in 2012 by WMA, to define flood behaviour and current conditions. This study was undertaken in two parts: 1. Design Lake Water Levels and Wave Climate, and; 2. Foreshore Flooding.

Some key model parameters and modelling methodology that was utilised for this study are as follows:

- Water levels for Lake Macquarie were adopted as follows:
  - Extreme event: 2.63 mAHD
  - 1% AEP event: 1.38 mAHD
  - 2% AEP event: 1.24 mAHD
  - 5% AEP event: 0.97 mAHD
- Historical flood records from Jigadee Creek (Station number: 211008) were used to calibrate rainfall runoff into Lake Macquarie for this study.
- WBNM was used for hydrological modelling in this study.
- Flood hydrographs were estimated using AR&R 87 estimation methods, and BoM supplied local rainfall data for the longer duration storm events.
- Sub-catchment details for the Dora Creek catchment were as follows:
  - Area: 220 km^2
  - Percentage of total Dora Creek catchment area: 30%
  - Rural catchment
- WBNM calibration was undertaken using the recorded flood hydrographs from the Jigadee Creek gauge during February 1981 and February 1990 flood events. The outcomes from this calibration were combined with the recommended design rainfall losses from AR&R (1987) to derive the final model input parameters (see Table 2.3 below).
- Hydraulic modelling was completed using the computer based finite element model RMA-2.
- Calibration and verification of the hydraulic model was undertaken to the following storm events:
  - November 1986 – rainfall event
  - March 1990 – storm surge event
  - May 1974 – storm event

TABLE 2.3: FINAL WBNM INPUTS – FROM 2012 STUDY

Location	C (lag factor)	n (streamflow routing factor)	Initial Loss (IL)	Continuing Loss (CL)
Calibration	2.3	0.23	80 mm	4 mm/hr (urban) 3 mm/hr (rural)
AR&R 1987	-	-	25 mm	2.5 mm/hr
Combined – Final Inputs	2.3	0.23	25 mm (rural) 10 mm (urban)	2.5 mm/hr (rural) 1.5 mm/hr (urban)

2.2.4 Dora Creek: Floodplain Management Plan – June 1998

This management plan was prepared by the Department of Land and Water Conservation for Council. It provides the basis for the future management of flood liable lands and the management of development within the Dora Creek floodplain. Both structural and non-structural flood mitigation options have been explored within this plan. Pervious flood studies were referred to in developing the management strategies.

2.2.5 Dora Creek Flood Study – May 2015

The study was completed for Council by WMA Water (WMA) to reassess design flood levels considering updated data and technology and to incorporate sea level rise benchmarks based on predictions by the Intergovernmental Panel on Climate Change (IPCC) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) technical review for Australia, and also the potential increase in rainfall intensities due to climate change. The study was undertaken to meet the requirements of the Floodplain Development Manual (NSW DIPNR 2005).

The key model parameters and modelling methodology that was utilised in this study, including updates compared to previous modelling, are as follows:

- A Watershed Bounded Network Model (WBNM) was developed for the Dora Creek catchment and sub catchments.
- This hydrologic model was calibrated to the March 1977, February 1981, June 1989, February 1990, June 2007, and February 2013 events through adjustment of the lag parameter (C value) and rainfall losses. Final parameter values are presented in Table 2.4, event parameters have only been presented where Mandalong gauge data calibration was undertaken.
- The 1D/2D hydraulic modelling software package TUFLOW (version: 2012-05-AE-w64) was used, with most of the Stockton Creek channel built in 1D.
- 10m grid size utilised.
- Dora Creek bathymetric and LiDAR survey was incorporated into the model.
- The adopted Manning's 'n' values are presented in Table 2.5 below.

TABLE 2.4: FINAL WBNM INPUTS – WMA 2015

Event	Initial Loss (mm)	Continuing Loss (mm)	Lag Parmeter C Value
February 1989	30	2.5	2.4
February 2007	10	2.5	
February 2013	40	2.5	
Design Event Runs	10	2.5	

TABLE 2.5: ADOPTED MANNINGS N VALUES – TUFLOW MODEL

Model Domain	Land Use/ Location	Manning's *n*
2D	Roads and Pavement	0.015
2D	Rural	0.045
2D	Urban Residential	0.04
2D	Commercial/ Industrial	0.04
2D	Light Vegetation	0.03
2D	Heavy Vegetation	0.09
1D	Upper Dora Creek Waterway	0.08
1D	Upper Jigadee Creek Waterway	0.08
1D	Upper Stockton Creek Waterway	0.07
1D	Lower Dora Creek and Lake Waterway	0.02

2.2.6 Dora Creek Floodplain Risk Management Study and Plan – June 2015

The management plan was completed for Council by WMA as an update for previously completed flood management studies and was developed based on the outcomes of the Dora Creek Flood Study (2015). The NSW Government's benchmarks for sea level rise, as well as guidelines for rainfall intensity increases have been incorporated into the plan.

2.2.7 Mandalong Coal Mine Flood Study – Engeny, 2022

Engeny have previously developed hydraulic models for the Mandalong area using the Tuflow modelling software. These model builds have been referred to when developing the flood model for this assessment, particularly for the structure specifications upstream of the M1 Motorway.

2.3 Relevant Legislation & Guidelines

- Australian Rainfall & Runoff (ARR), Ball, et. al. (2019) – Provides a detailed methodology for the estimation of design storm events, hydrological and hydraulic flood modelling.
- Floodplain Development Manual (FDM), NSW Department of Infrastructure, Planning and Natural Resources (2005) – guideline to requirements for development on a floodplain, including definition of flood function and flood hazards.
- Floodplain Risk Management Guide (FRMG, NSW Department of Planning and Environment (2023) – replaces the FDM
- LMCC's policies on climate change and sea level rise (https://www.lakemac.com.au/Development/Building-and-development-process/Development-in-areas-affected-by-sea-level-rise) – provides guidance on the planning requirements for coastal and estuarine areas affected by sea level rise.

3. AVAILABLE DATA

A comprehensive review of available data was undertaken in the initial stages of this Project. This section provides an overview of the data used to develop the hydrologic and hydraulic models and derive the outcomes of this flood study.

3.1 Rainfall Data

A summary of the rainfall gauges located within the vicinity of the study area is provided in Table 3.1, these gauges are also displayed on Figure 2.2. The MHL rainfall gauge at Deaves Road, Mandalong was considered most appropriate for use in this assessment, as 30 years of pluviographic data is available, and it is located within the Stockton Creek catchment.

TABLE 3.1: AVAILABLE RAINFALL GAUGES

Gauge Name	Gauge ID	Gauge Website	Available Data	Years of Data
Mandalong at Deaves Road	561081	MHL	Pluviometer	30 years (1994-current)
Martinsville	561083	MHL	Pluviometer	29 years (1995 – current)
Wyong (Olney Forest)	61385	Bureau of Meteorology	Daily total	23 years (2000 – 2023)
Dora Creek (Cooranbong Road)	61323	Bureau of Meteorology	Daily total	21 years (1972- 1993)
Cooranbong (Avondale)	61012	Bureau of Meteorology	Daily total	121 years (1903 – current)
Dora Creek (Dora Street)	61282	Bureau of Meteorology	Daily total	117 years (1907- current)
Morisset	61276	Bureau of Meteorology	Daily total	4 years (1911- 1915)
Mandalong (Mandalong Road)	61257	Bureau of Meteorology	Daily total	86 years (1894 – 1980)
Dooralong	61219	Bureau of Meteorology	Daily total	13 years (1963- 1976)
Wyee (Rutleys Road)	61389	Bureau of Meteorology	Daily total	14 years (1997- 2011)
Wyee Post Office	61082	Bureau of Meteorology	Daily total	118 years (1899-2017)

3.2 Level and Flow Data

The Jigadee Creek at Avondale gauge is the only gauge within the catchment which has an associated flow rating curve. The gauge has been actively monitoring data since December 7, 1969 and has 55 years of data. The gauge control is a V notch concrete weir of approximately 9 m width (refer to Figure 3.1 below).

The gauge is situated at an elevation of 18.906 meters above the Australian Height Datum (AHD). The highest recorded stage at this gauge was 3.100 meters, which occurred on June 21, 1975. Three rating tables have been used at this site since its inception, with significant updates on November 14, 1973, and August 27, 1974. A total of 107 gaugings have been conducted between December 17, 1969, and February 6, 2018. Several cross-sectional surveys have been conducted at the site, with notable ones on July 31, 2003, October 2, 2014, November 14, 2005, June 8, 2021, September 6, 2022, and July 18, 2024. These surveys help understand the channel geometry and flow dynamics at various sections of the creek.

A summary of the level and flow gauges within the vicinity of the project area is provided in Table 3.2.

FIGURE 3.1: JIGADEE CREEK AT AVONDALE (SOURCE WATERNSW)

The level data from MHLs Morisset and Kalang Road gauges are located within, and just downstream of the study area respectively. The Morisset gauge is located close to the Stockton Creek outlet into Dora Creek, and the Kalang Road gauge is located further downstream in Dora Creek approximately 1 km from the hydraulic model's downstream boundary.

No rating curve has been developed for these gauges however, and it was beyond the scope of this study to develop one. Level data from these gauges was used during the hydraulic model calibration, which is considered appropriate as the hydraulic model provides flood level estimates. further detail on this process is provided in Section 5. Figure 3.2 and Figure 3.3 show the Morisset and Kalang Road gauges.

FIGURE 3.2: MHL MORISSET GAUGE

FIGURE 3.3: MHL KALANG ROAD GAUGE

TABLE 3.2: AVAILABLE FLOW AND LEVEL GAUGES

Gauge Name	Gauge ID	Gauge Website	Data frequency/ Type
Morisset	211480	MHL	Level only, 15-minute data
Kalang Road	211475	MHL	Level only, 15-minute data
Cooranbong	211470	MHL	Level only, 15-minute data
Jigadee Creek at Avondale	211008	WaterNSW	Level and flow (55 years of data)

3.3 Design IFD Data

Design rainfall data for the Stockton Creek catchment was derived for rainfall events between 50% AEP event and the Probable Maximum Precipitation (PMP) event. Design rainfall was derived using the following methods:

- Rainfall totals in the AEP range 50% AEP to 0.02% AEP were generated for the catchment using Storm Injectors BoM IFD interface tool (www.bom.gov.au/water/designRainfalls/revised-ifd/).

  The rainfall was spatially distributed across the catchment extent, with rainfall point estimates from four IFD points being applied.
- Probable maximum Precipitation (PMP) rainfall estimates were calculated using the GSDM method (BOM, 2003) for durations less than 6 hours.

Design rainfall totals (point values) at the catchments central IFD location (easting of 359307.07, northing of 6338079.78) is summarised in Table 3.3.

3.4 Topographic and Bathymetric Survey

LiDAR for the study area was downloaded from ICSM's ELVIS website (https://elevation.fsdf.org.au/) and supplemented in the Dora Creek and lower Stockton Creek area by bathymetry sourced from OEH. A summary of the available survey data is provided below in Table 3.4.

TABLE 3.3: EXAMPLE DESIGN RAINFALL INTENSITIES (AEP) APPLIED TO THE CATCHMENT (MM)

Storm Duration	63% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
30 minutes	20.1	23	32.7	40.1	47.9	59.3	68.8
45 minutes	23.5	26.9	38.3	46.9	56	69.1	80.1
1 hour	26.1	29.8	42.5	52	62	76.4	88.4
1.5 hour	30.1	34.4	48.9	59.7	71.1	87.5	101
2 hours	33.2	38	53.9	65.8	78.3	96.2	111
3 hours	38.4	43.8	62.1	75.7	89.9	110	127
4.5 hours	44.5	50.8	71.9	87.6	104	127	147
6 hours	49.6	56.6	80.2	97.6	116	142	164
9 hours	58.1	66.3	93.9	114	136	167	193
12 hours	65.1	74.3	105	129	153	188	218

Storm Duration	63% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
18 hours	76.2	87.1	124	152	181	223	259
24 hours	85	97.3	139	171	204	252	293
30 hours	92.2	106	152	186	223	276	320
36 hours	98.2	113	162	200	240	297	344
48 hours	108	124	179	221	266	329	381
72 hours	**121**	**139**	**202**	**250**	**301**	**372**	**429**

TABLE 3.4: SUMMARY OF AVAILABLE TOPOGRAPHIC AND BATHYMETRIC SURVEY DATA

Type	Source	Date	Details	Suitable for Use
LiDAR	ELVIS	2014	Full catchment coverage at 1m cell size	Yes
Bathymetry	OEH	2012	Dora Creek and Stockton Creek main channel extents	Yes – however, required manual processing

3.5 Structure Survey

3.5.1 Bridges

Council have limited bridge survey available for the study area, so an estimation of dimensions was made based on google earth and site inspection observations. To ensure reasonable dimensions have been utilised, a comparison to the modelled bridge crossings within the Dora Creek Flood Study (WMA, 2015) was undertaken. The following bridges have been incorporated into the hydraulic model:

- Ten bridges along the M1 motorway:
  - Two crossing Stockton Creek
  - Four crossing a Stockton Creek tributary.
  - Two crossing Dora Creek.
  - Two crossing Freemans Drive.
- One bridge at Freemans Drive crossing Stockton Creek.
- One bridge along Mandalong Road crossing the M1 motorway.
- One bridge along Freemans Drive crossing Dora Creek.
- One bridge along Newport Drive crossing Jigadee Creek.
- Two bridges along Main Road crossing Dora Creek.

3.5.2 Culverts, Pits, and Pipes

Council provided shapefiles for the culverts, pits, and pipes throughout the study area. However, gaps were evident in the data and estimation of dimensions and inverts was required. Table 3.5 comments on the data provided and estimation required for input of data into the hydraulic model.

TABLE 3.5: CULVERT DATA

Data	Details Provided	Estimation Required
Culverts	All culvert sizes available. No inverts available for any culverts within the hydraulic model extent.	Inverts and culvert lengths were estimated based on available LiDAR.
Pipes	Most pipe sizes were provided in the data, however, no invert levels for pipes within the hydraulic model extent were available.	Inverts and pipe lengths were estimated based on LiDAR, minimum cover, and minimum grade for pipe size requirements. The maintenance of network continuity was also considered in the estimation.
Pits	Only pit location provided.	Google earth street view imagery was used to infer pit inlet dimensions.

3.6 Flood Marks

Council provided a shapefile of available flood marks within the vicinity of the study area, an overview of the flood marks available within the hydraulic model boundary per year is presented in Table 3.6.

TABLE 3.6: FLOOD MARKS

Year	Level Markers Available	Year	Level Markers Available
1927	1	1988	1
1949	3	1989	20
1953	1	1990	17
1955	2	1992	1
1975	1	2007	5
1977	26	2015	5
1978	5	Unknown	11
1981	3		

3.7 Resident Data Survey

As part of this flood study, a resident survey (Appendix A) was undertaken to gain an understanding of the study areas:

- Historic flood behaviour.
- Obtain historic food levels.
- Obtain flooding photographs.
- Obtain information relevant to the flood study.

4. FLOOD ASSESSMENT

4.1 Hydrologic Modelling Methodology

Hydrologic modelling was undertaken using the WBNM software package. The catchment and sub-catchment gross hydrological response has been assessed to estimate the potential critical storm durations and temporal patterns. The critical duration storm and temporal pattern hydrographs were then inputted as inflows into the hydraulic modelling software (refer to Section 4.2 below).

The key hydrologic modelling parameters are summarised in Table 1.

4.1.1 Modelled Events

All ensemble temporal patterns for 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP and PMF flood events (estimated from ARR 2019) have been simulated in Storm Injector for the determined critical durations. The local or total sub catchment outputs for the critical duration of each AEP have been input into the hydraulic model. See below Table 4.1 for the critical duration determined for each event.

Climate change scenarios have also been considered for the 1% AEP; with increased rainfall intensity (10% and 20%) as well as sea level rise (SLR) (+0.4 m and +0.9 m) assessed.

4.1.2 Critical Durations

For each modelled AEP event varied critical durations were displayed within the vicinity of Morisset, within the key study area (see Figure 2.1). Due to this, hydrology was processed for the whole suite of temporal patterns for the 30 minute to the 12 hour durations, and input into the hydraulic model.

4.1.3 Model Overview

An overview of the WBNM model is presented below in Figure 4.1.

TABLE 4.1: HYDROLOGIC MODEL PARAMETER SUMMARY

Parameter	Specification
Rainfall Losses	AEP events - Model losses were determined based on the results of the historical storm event calibration (see Section 5.1) and FFA validation (see Section 5.2). PMP – zero losses.
Area Reduction Factor (ARF)	ARFs have been applied to the model for the 3 main catchments within the model (Jigadee, Stockton, and the broader Dora Creek catchment area). They were calculated based on catchment size within the storm injector software product.
Rainfall Depths	IFD has been applied to hydrologic model using Storm Injector's BoM IFD import tool. Refer to Section 3.3 for IFD details.
Temporal Patterns	≤1% AEP, ten temporal patterns as per ARR2019; > 1% AEP and short duration, 10 temporal patterns from Jordan et al. (2005) as recommended in ARR2019, > 1% AEP and long duration, GSTMR temporal patterns if applicable.
Catchment Slope	No catchment slope calculation in WBNM, as this is not an input parameter for this model.
Catchment Impervious Fraction	Fraction impervious values per land use type were confirmed with Council and were spatially weighted per catchment dependent of presence of land uses. The Environmental Planning Instrument (EPI) Land Zoning shapefile was used to determine the land use present throughout the catchment, with land use confirmed through aerial imagery assessment. The following fraction impervious values to match the land use categorisation in the catchment area have been adopted in this assessment.

Land Use	Fraction Impervious (%)	Land Use	Fraction Impervious (%)	Land Use	Fraction Impervious (%)
Forestry	0	General Industrial	90	Low Density Residential	55
Public Recreation	20	Rural Landscape	2	Environmental Conservation	0
National Parks and Nature Reserves	0	Special Activities	90	Transition	10
Environmental Management	0	Infrastructure	90	Medium Density Residential	55
Mixed Use	90	Local Centre	90	Commercial Centre	90
Productivity Support	10	Private Recreation	20		
Primary Production Small Lots	10	Natural Waterways	0		

Parameter	Specification
Routing Links	WBNM routes through the catchments based upon the stream or catchment parameters. See Figure 4.1 for an overview of the model.

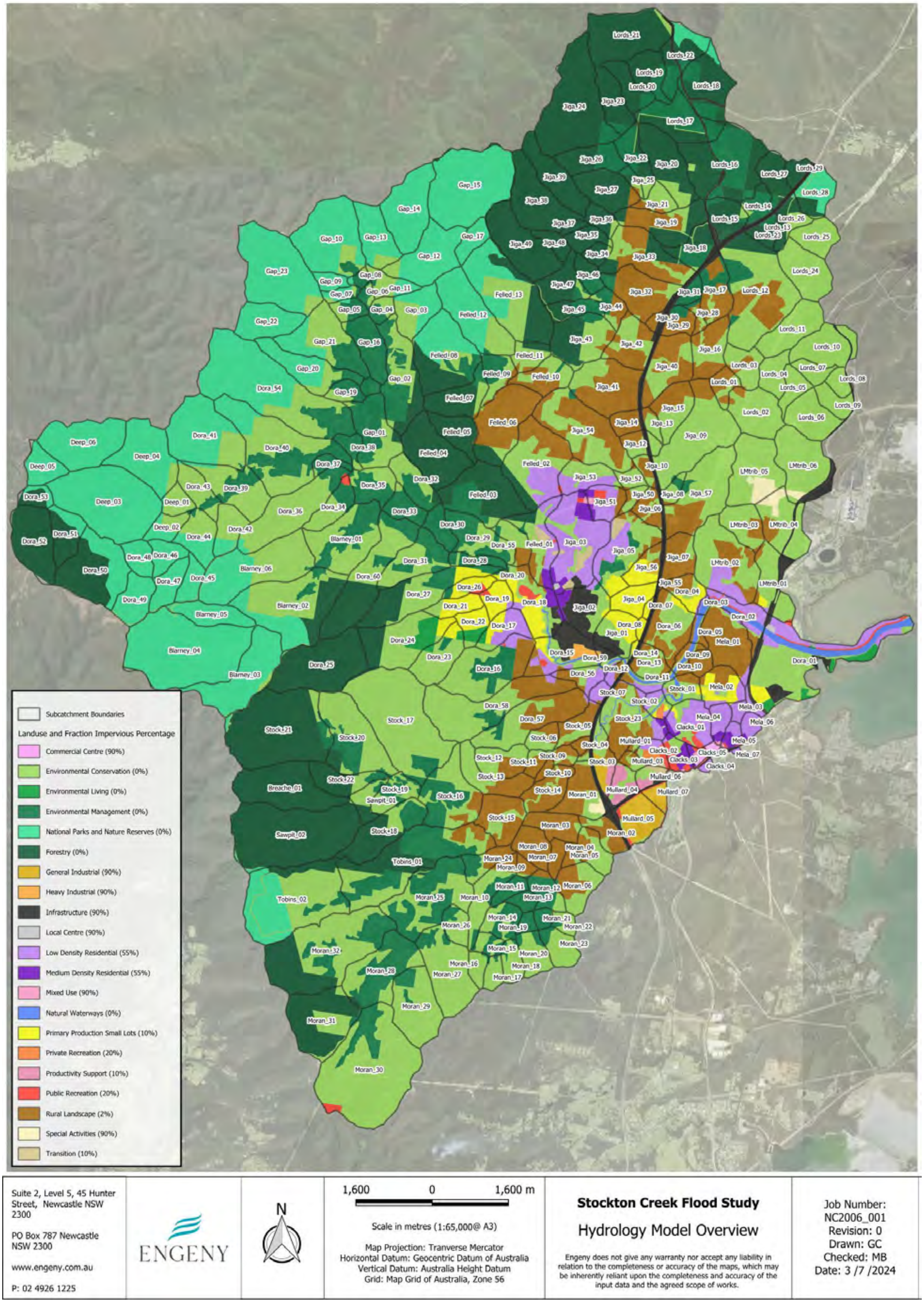

FIGURE 4.1: HYDROLOGIC MODEL OVERVIEW

4.2 Hydraulic Modelling Methodology

Hydraulic modelling has been undertaken using the TUFLOW software package (version 2023-10-AB), utilising the Highly Parallelised Computer (HPC) scheme. The TUFLOW modelling software has been used extensively throughout Australia for similar flood studies. A dynamically linked 1D/2D model has been developed, which includes the floodplain and all tributaries of Dora Creek within the two-dimensional (2D) model domain, and bridge and culverts incorporated in the one-dimensional (1D) domain.

The following sections outline the key hydraulic modelling input parameters adopted in the modelling.

4.2.1 Topography and Model Extent

The TUFLOW model has utilised the publicly available 1 m Digital Elevation Model (DEM) based on NSW Land and Property Information Centre (LPI) LiDAR data. This LiDAR has been supplemented by OEH bathymetry for the lower Dora Creek and Stockton Creek channel areas.

4.2.2 Grid Size and Time Step

Following an analysis of typical sections of the waterway area within the hydraulic model extent and review of available LiDAR, a 6 m grid cell size was considered appropriate for providing sufficient definition of the watercourses in the model domain without significantly increasing model simulation times. Hydraulic structures, such as bridges, are incorporated separately as 1D elements.

The adopted model time step of 1.5 seconds has provided stable model configuration.

4.2.3 Model Parameters

The key hydraulic input parameters are outlined in Table 4.2.

4.2.4 Downstream Tail Water Conditions

Downstream tail water conditions need to consider the presence of coincident rainfall induced and ocean induced flooding mechanism. Previous studies undertaken by Council have undertaken significant investigations in the flooding in both Lake Macquarie, and in its smaller and larger tributaries.

The previous tailwater conditions used within WMA (2015) modelling have been adopted, as they were deemed suitable for the study and generally consistent with the requirements of ARR 2019. It is notated that the tailwater conditions are dominated by levels within Lake Macquarie, which provides a relatively steady tailwater boundary. Table 4.3 below provides an overview of the tailwater conditions adopted for each AEP event. The influence of downstream tail water conditions on flooding has been considered in the model parameter sensitivity analysis.

For the historical event calibration runs the level time series from the Belmont MHL gauge (gauge number: 211461) within Lake Macquarie was adopted for the tail water conditions. This gauge was chosen as it is the only one within the lake extent that has level data available for every event. Table 4.4 below provides an overview of the peak lake levels for each historical event.

4.2.5 Hydraulic Model Duration and Ensemble Selection

The critical durations and temporal patterns ran through the hydraulic model for 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP and PMF flood events are presented in Section 4.1.1. The critical duration for each design storm event was identified as that which results in the highest flood level within any point in the model, with the median design temporal pattern. It is noted that the critical duration (and median temporal pattern) will vary across the model domain, and the resulting figures are based on the maximum flood level at each point within the model domain.

4.2.6 Model Parameter Sensitivity

Sensitivity scenarios have been undertaken during the model verification and design storm modelling (for 1% AEP design storm), to understand which parameters are the most influential on the peak flood levels results. The sensitivity scenarios investigated have included:

- Blockage of pipes/bridges/culverts (likely, upper, and lower blockage based on ARR19).
- Hydrologic catchment lag parameter (C) varied by ±25%.
- Rainfall losses varied by ±25%.
- Mannings roughness varied by ±25%.
- Downstream boundary varied by ±0.5 m.

4.2.7 Model Overview

An overview of the TUFLOW model extent is presented in Figure 4.2.

TABLE 4.2: HYRAULIC MODEL PARAMETERS

<table>
<tr><th>Parameter</th><th>Specification</th></tr>
<tr><td>Roughness Values</td><td>The hydraulic roughness (Manning’s ‘n’) applied in the TUFLOW model has been based on the existing land cover conditions obtained from Google Earth aerial imagery dated 2023 and model calibration outcomes.
<table>
<tr><th>Land Use</th><th>Manning’s ‘n’ Roughness</th></tr>
<tr><td>High Density Residential</td><td>0.4</td></tr>
<tr><td>Low Density Residential</td><td>0.3</td></tr>
<tr><td>Roads and Hardstand</td><td>0.03</td></tr>
<tr><td>Grassed Area (Low Density Vegetation)</td><td>0.035</td></tr>
<tr><td>Open Water</td><td>0.05</td></tr>
<tr><td>Medium Density Vegetation</td><td>0.05</td></tr>
<tr><td>High Density Vegetation</td><td>0.09</td></tr>
<tr><td>Vegetated Channel</td><td>0.08</td></tr>
<tr><td>Non-vegetated Channel</td><td>0.05</td></tr>
</table>
</td></tr>
<tr><td>Hydraulic Structure Representation</td><td>Culvert structures: larger than 300 mm connecting the overland flow paths and waterway have been incorporated into the model as 1D network elements connected to the 2D domain via SX connections. Culvert parameters were based off Council provided datasets and have been estimated based on LiDAR and google satellite imagery where required.
Stormwater Pipes: equal to or larger than a diameter of 450 mm was included in the hydraulic model. Sizes, inverts, and other parameters were taken from the Council’s GIS data where available. Where unavailable, estimations were made as laid out in Section 3.5.2.
Stormwater Pit: location data was provided by Council. Pit inlet dimensions were estimated as laid out in laid out in Section 3.5.2.
Bridges: were represented through 2D Layered Flow Constriction model layers, with key dimension data provided by Council or estimated based on LiDAR and google satellite imagery in lieu of Council data. These estimations were confirmed against the bridge dimensions utilised within the 2015 WMA study.
Blockage factors have been applied to both bridge and culvert structures in accordance with ARR19 procedures.</td></tr>
<tr><td>Inflow Boundary Conditions</td><td>Inflows have been applied within the 2D model domain via the extracted hydrographs from the WBNM catchment outputs. The inflow hydrographs have been applied locally to stormwater pits via 1d_bc layers where possible, and as source-area inflows via 2d_sa layers for the remainder of inflow locations.</td></tr>
<tr><td>Critical Durations</td><td>As outlined in Section 4.1.2, the critical durations varied across the study area and therefore results were run for the 30 minute to the 12-hour duration storm, for all ten temporal patterns. Results for the maximum of the median temporal patterns for each duration have been presented for the flood depth, velocity, and hazard categorisation.</td></tr>
</table>

TABLE 4.3: AEP EVENT TAILWATER CONDITIONS

AEP Event	Tailwater (mAHD)
50%	0.7
20%	0.82
10%	0.94
5%	1.23
2%	1.23
1%	1.23
0.5%	1.23
0.2%	1.23
PMF	2.45

TABLE 4.4: CALIBRATION EVENTS – TAILWATER CONDITIONS

Historical Event	Peak Lake Level (mAHD)
1989	0.6
2007	1.1
2015	1.0
2022	0.7

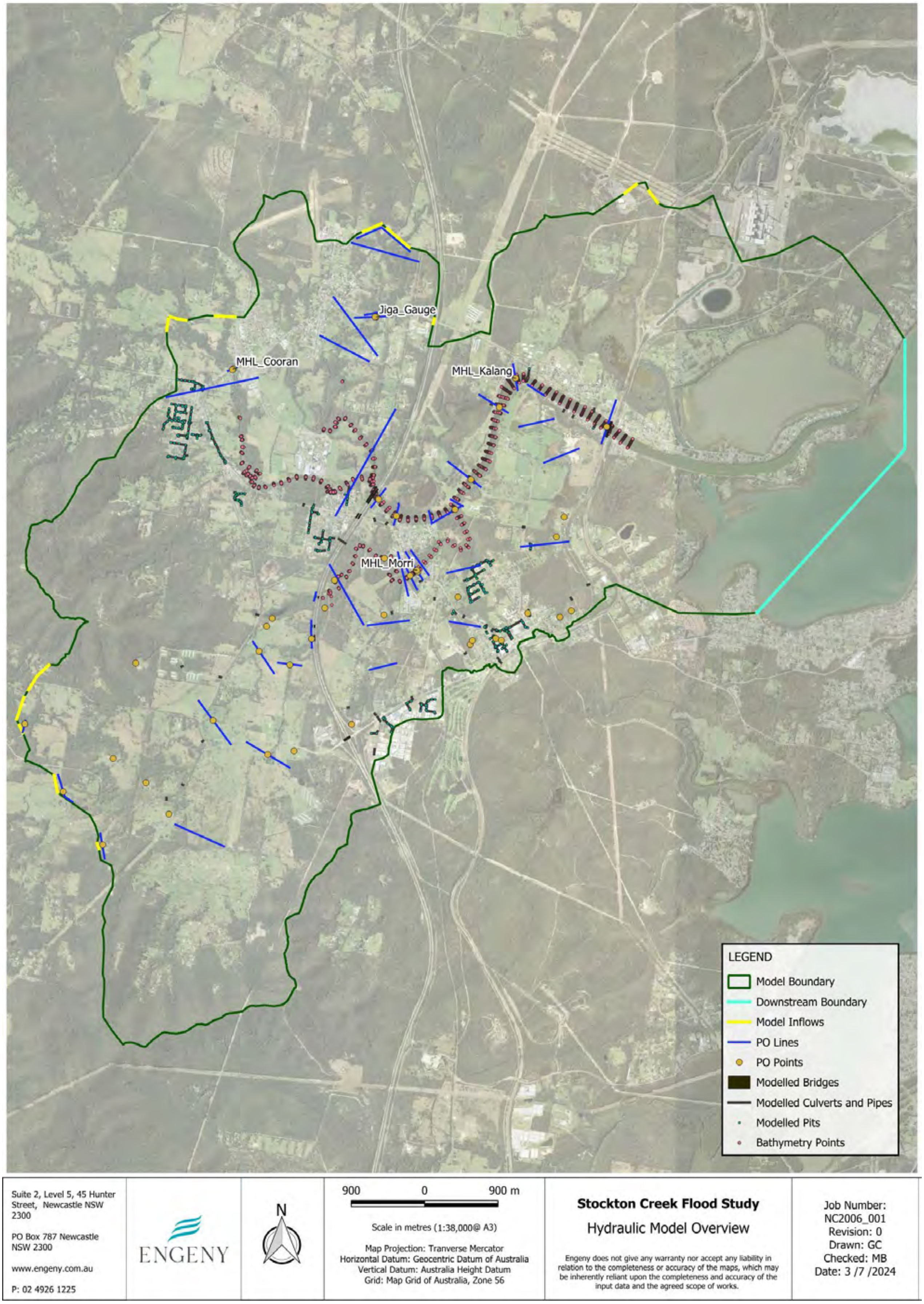

FIGURE 4.2: HYDRAULIC MODEL OVERVIEW

5. MODEL VERIFICATION

5.1 Rainfall Event Calibration

A joint hydrologic and hydraulic model calibration to historical rainfall events was undertaken using the following methodology:

- Varying of initial and continuing losses, and the pervious lag routing parameter in the hydrologic (WBNM) model to assess the impact on the timing of peak flows at the Jigadee gauge (WaterNSW gauge number 211008).
- Input of the WBNM model output flows into the hydraulic (TUFLOW) model, and then a comparison of the TUFLOW peak levels and timing results against the recorded levels at the following gauges:
  - Jigadee Gauge (WaterNSW gauge: 211008).
  - Morisset Gauge (MHL gauge: 211480).
  - Kalang Road gauge (MHL gauge: 211475).
  - Cooranbong gauge (MHL gauge: 211470).
- The manual adjustment of model parameters was repeated to achieve a suitable fit for each event. Achieving a better fit to flood levels in the hydraulic model was prioritized in selecting the final calibrated parameters.
- The calibrated parameters were then used to determine AEP event run parameters, refer to Section 5.3.

Results of the historical event calibration are presented in Section 5.1.3 to Section 5.1.5, and Table 5.1 provides an overview of the calibrated parameters for each event.

TABLE 5.1: CALIBRATED EVENT PARAMETERS

Event	Initial Loss	Continuing Loss	Lag Parameter (C)
1989	20	5	2.4
2007	50	8	4.8
2015	40	6.5	5.5
2022	50	4	4.8

5.1.1 Historical Event Summary

Details of the historical rainfall events selected for model calibration are presented in Table 5.2.

TABLE 5.2: SELECTED RAINFALL EVENT DETAILS

Rainfall Event	Start Date/ Time	End Date/ Time	Data Frequency	Duration of Event (Days)	Mandalong Gauge - Total Rainfall (mm)	Martinsville Gauge – Total Rainfall (mm)
1989	19/06/1989 9:00	21/06/1989 9:00	5 minute	2.0	209.5	272.0
2007	7/06/2007 9:00	9/06/2007 9:00	5 minute	2.0	266.5	291.0
2015	19/04/2015 0:00	23/04/2015 0:00	Tipping Bucket	4.0	254.9	254.0
2022	1/07/2022 20:00	7/07/2022 9:00	Tipping Bucket	5.5	382.0	378.5

These events were selected through analysis of historical rainfall recorded at the MHL Mandalong and Martinsville gauges. The four peak daily rainfall events observed simultaneously for both gauges were selected, refer to Figure 5.1.

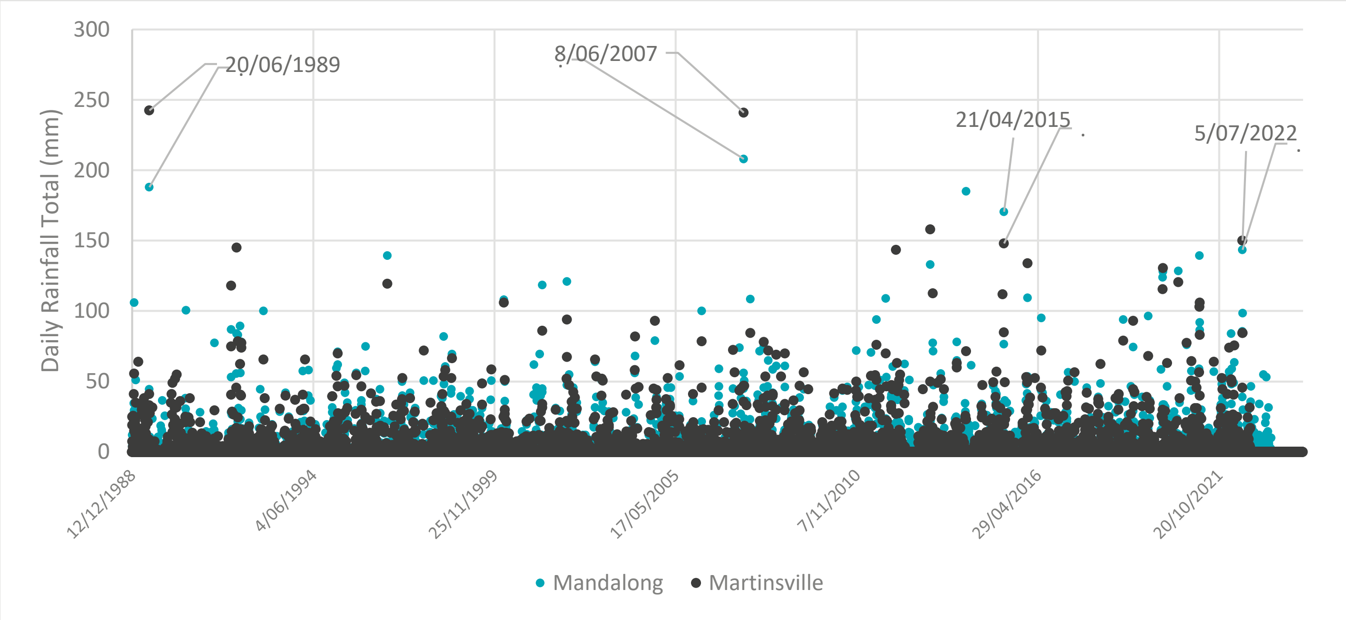

FIGURE 5.1: MHL MANDALONG AND MARTINSVILLE GAUGES DAILY RAINFALL (MM)

5.1.2 1989 Event

The 1989 event occurred from the 19 June 1989 to the 21 June 1989.

Figure 5.2 presents a comparison of the modelled (WBNM) and recorded flow at the Jigadee gauge. Results show a decent match of storm timing, however, a perfect match of the rising and falling limbs, and modelled peak has not been achieved. As such, results of this event were not the focus of the calibration and instead the three more recent events (below sections) drove AEP event parameter finalization (see Section 5.3).

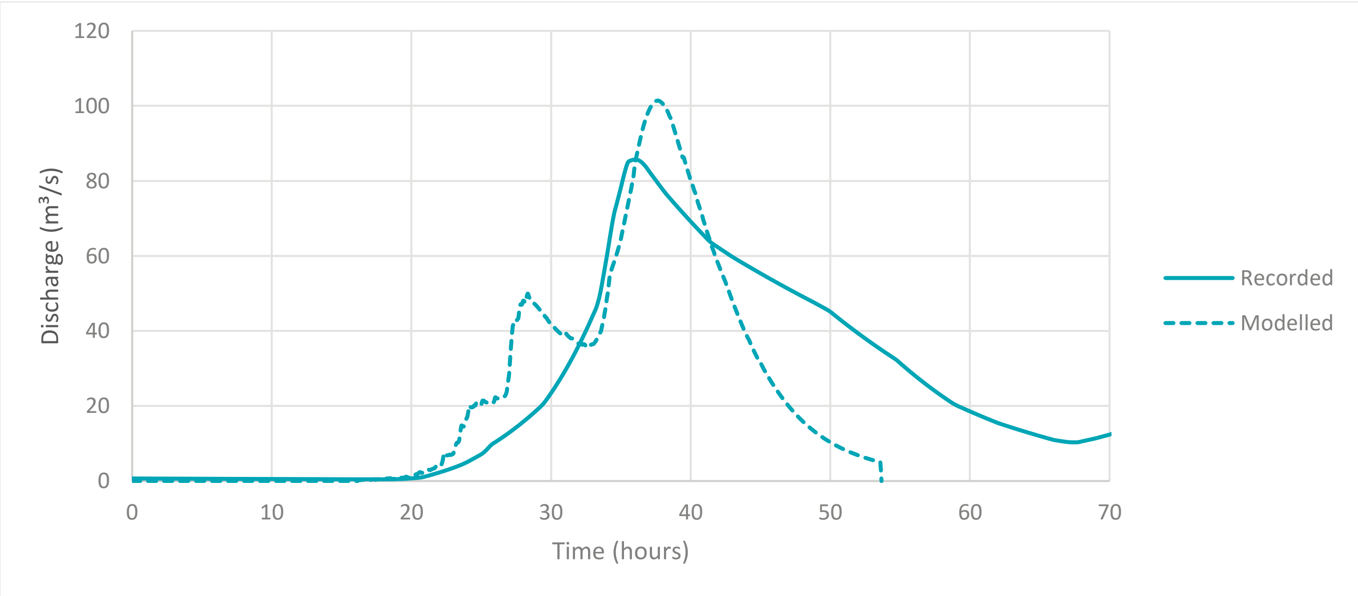

FIGURE 5.2: 1989 EVENT - HYDROLOGY MODEL RESULTS – FLOW (M^3/S)

Figure 5.3 presents a comparison of modelled (TUFLOW) and recorded levels at the available level gauges throughout the Dora Creek catchment. Only the Jigadee and Morisset gauges had level data available for this event.

Results show that the calibration peaks were slightly higher at both gauges than recorded, reaching a level of 5.3 m compared to 5.0 m at Jigadee gauge and 2.3 m compared to 2.2 m at the Morisset gauge. The rising and falling limbs of the modelled flows at the Jigadee gauge do not match up well to the recorded levels. However, the levels at this gauge are seen to occur around the same time. It should also be noted that the starting modelled levels at the Jigadee gauge do not match up with the recorded levels due to the location of where modelled results were extracted from (likely higher on banks than the gauge). The modelled levels at the Morisset gauge achieve a good match for the recorded levels, regarding the timing of the rising and falling limbs. Since the Morisset gauge sits within Stockton Creek and is closer to the study area of this assessment, priority for achieving a suitable fit to this gauge was made. As such, the model is considered reasonably calibrated for the 1989 event.

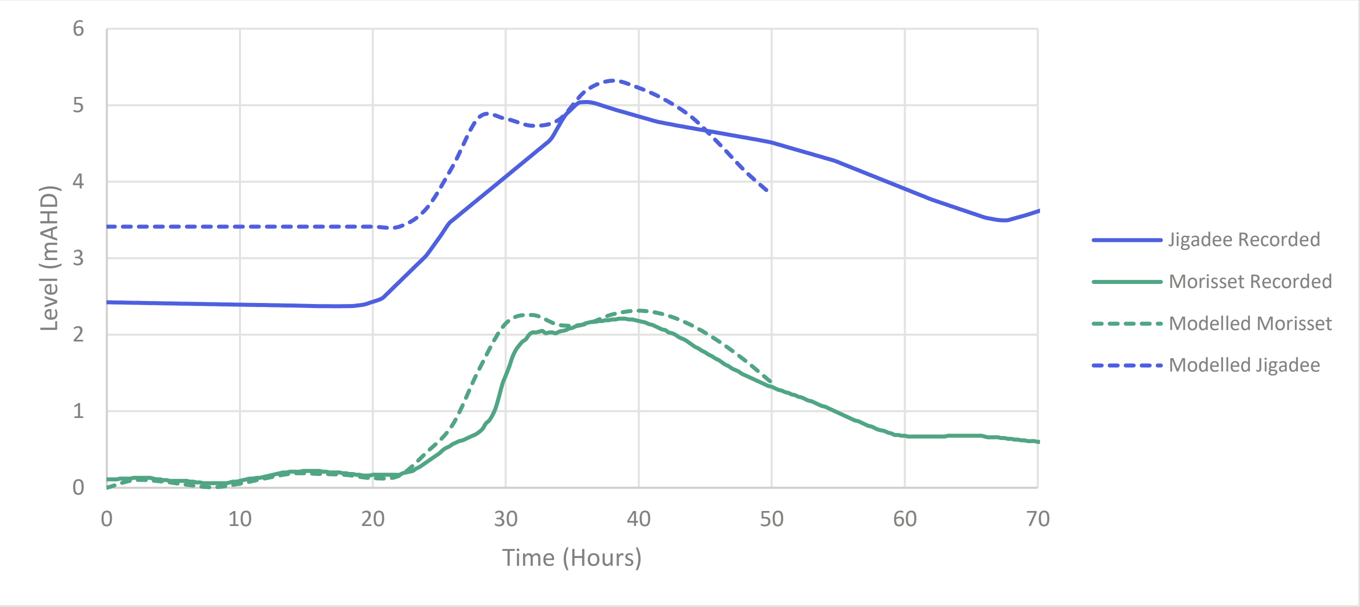

FIGURE 5.3: 1989 EVENT – HYDRAULIC MODEL RESULTS – LEVEL (MAHD)

5.1.3 June 2007 Event

The 2007 event occurred over the 7 June 2007 to the 9 June 2007.

Figure 5.4 presents a comparison of the modelled (WBNM) and recorded flows at the Jigadee gauge for the 2007 event. The modelled flows are slightly higher and occur slightly later than the modelled flows, at 156.7 m^3/s at approximately 39 hours and 151.7 m^3/s at approximately 38 hours respectively. Overall, results show a good match of modelled flows against recorded.

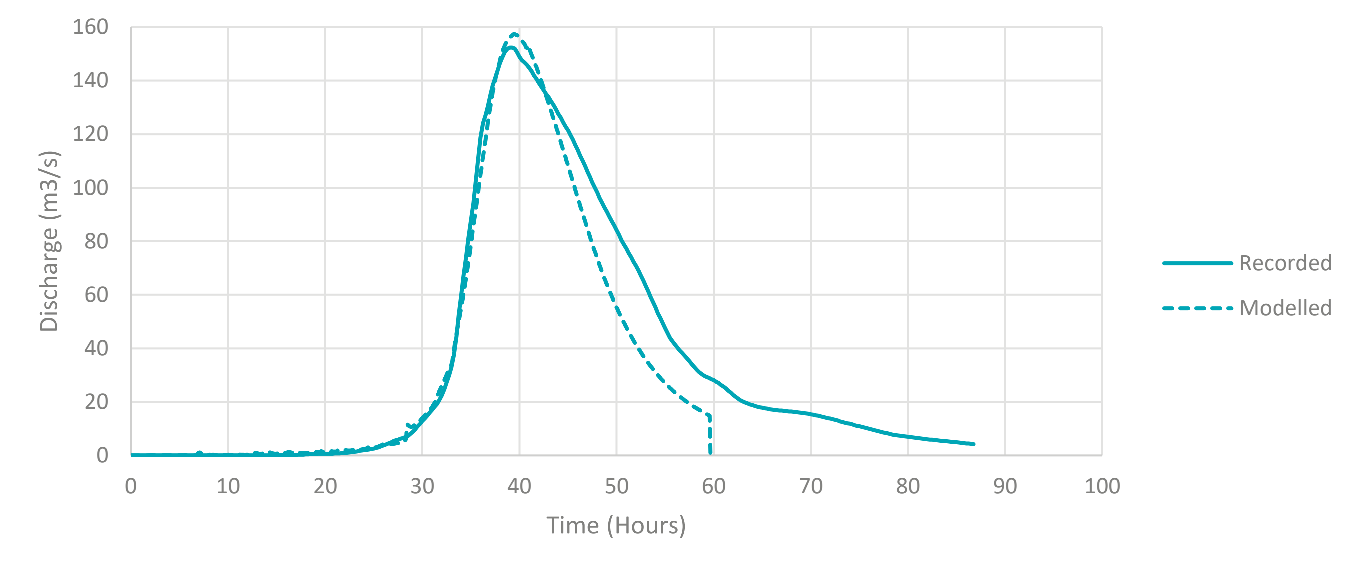

FIGURE 5.4: 2007 EVENT – HYDROLOGY MODEL RESULTS – FLOW (M³/S)

Figure 5.5 presents a comparison of modelled (TUFLOW) and recorded levels at the available level gauges throughout the Dora Creek catchment.

Modelled levels are slightly lower at the Jigadee and Cooranbong Road gauges than recorded, at 5.5 m compared to 5.6 m at Jigadee and 5.1 m compared to 5.4 m at the Cooranbong gauge. Since the focus area of this study is closer to the Morisset Creek gauge, a better calibration match at this location was favoured. Results for this gauge show an almost identical match of rising and falling limbs and peak levels, both reaching 2.6 m at approximately 44 hours. Results of the model against the Kalang Road gauge also display a near perfect match for the rising and falling limbs and peak level, with both peaks reaching approximately 2.2 m at approximately 46 hours. The modelled timing of peaks for each of the gauges provide a good match to the recorded. As such, a great calibration for the 2007 event has been achieved.

As with the other calibration events, it should be noted that the starting modelled levels at the Jigadee and Cooranbong gauge do not match up with the recorded levels. This is due to the location of where modelled results were pulled from (likely higher on banks than the gauge).

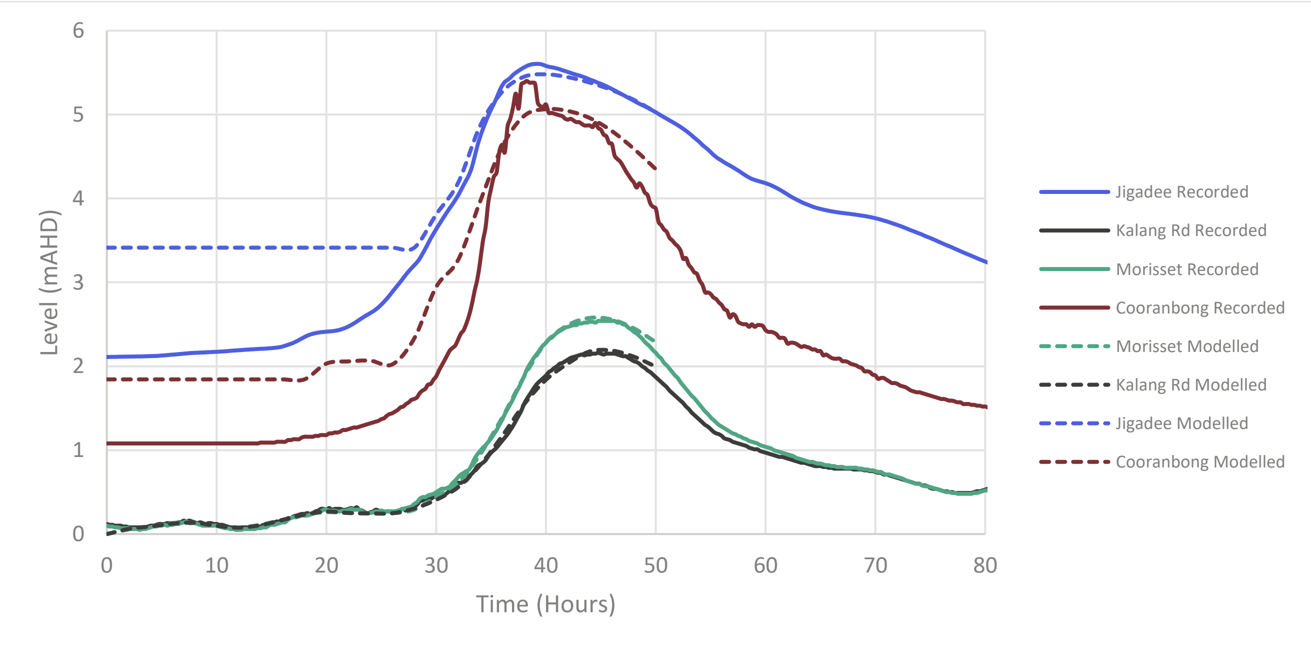

FIGURE 5.5: 2007 EVENT – HYDRAULIC MODEL RESULTS – LEVEL (MAHD)

5.1.4 2015 Event

The 2015 event occurred over the 19 April to the 23 April 2015.

Two sets of modelled results have been displayed for this event, as the best suited parameters for hydrology model did not achieve the best results for the hydraulic model. As such, final calibration results were chosen based on the best fit for hydraulic model levels, particularly for the Morisset gauge.

Figure 5.6 presents a comparison of the modelled (WBNM) and recorded flows at the Jigadee gauge for the 2015 event. The modelled parameters that achieved the best fit to recorded flows were with an initial loss of 40, a continuing loss of 1, and a pervious lag parameter of 5.5 and the final calibrated parameters for the 2015 event are presented in Table 5.1 above. The final calibration achieves a similar timing to the recorded storm with the peak flows occurring between 58 hours and 76 hours. However, the peak flow is much lower than the recorded at 54.5 m3/s compared to 120.2 m3/s.

Figure 5.7 displays the hydraulic model level results for the parameters that achieved the best fit for the WBNM model, these are not the final calibrated results. A near perfect match is attained for the Jigadee gauge levels. However, the modelled levels for the Cooranbong, Kalang Rd, and Morisset gauges are much higher than the recorded.

Figure 5.8 displays the final calibration results from the hydraulic model. The modelled levels are lower at the Jigadee gauge than recorded, with a peak of 4.9 m compared to 5.4 m. However, close matches to recorded peaks is achieved at each of the other gauges. Levels at Cooranbong have been modelled at 4.3 m compared to the recorded 4.4 m. Modelled levels are slightly higher at both Morisset and Kalang Road; being 2.0 m at Morisset compared to the recorded 1.9 m, and 1.7 m at Kalang Road compared to the recorded 1.6 m. A good timing and rising and falling limb match are achieved for each of the gauges.

As with the other historical calibration events, the modelled starting levels do not align exactly to the recorded for the Jigadee and Cooranbong gauges due to location differences of the gauge position and results export location.

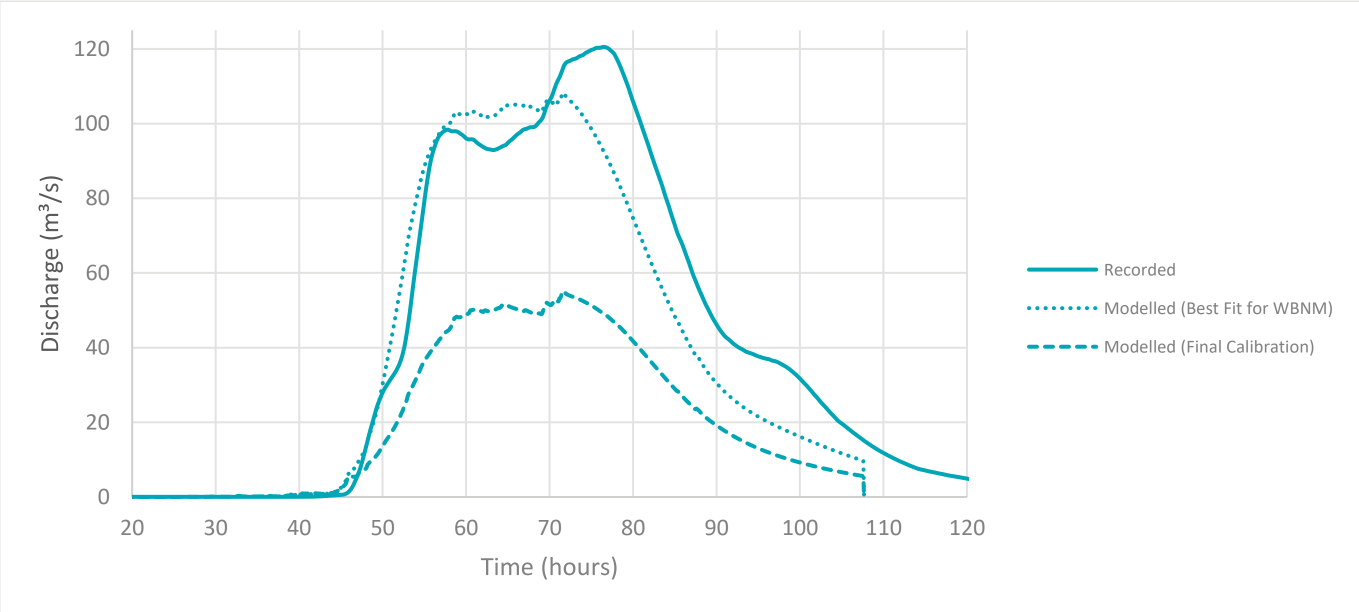

FIGURE 5.6: 2015 EVENT – HYDROLOGY MODEL RESULTS – FLOW (M^3/S)

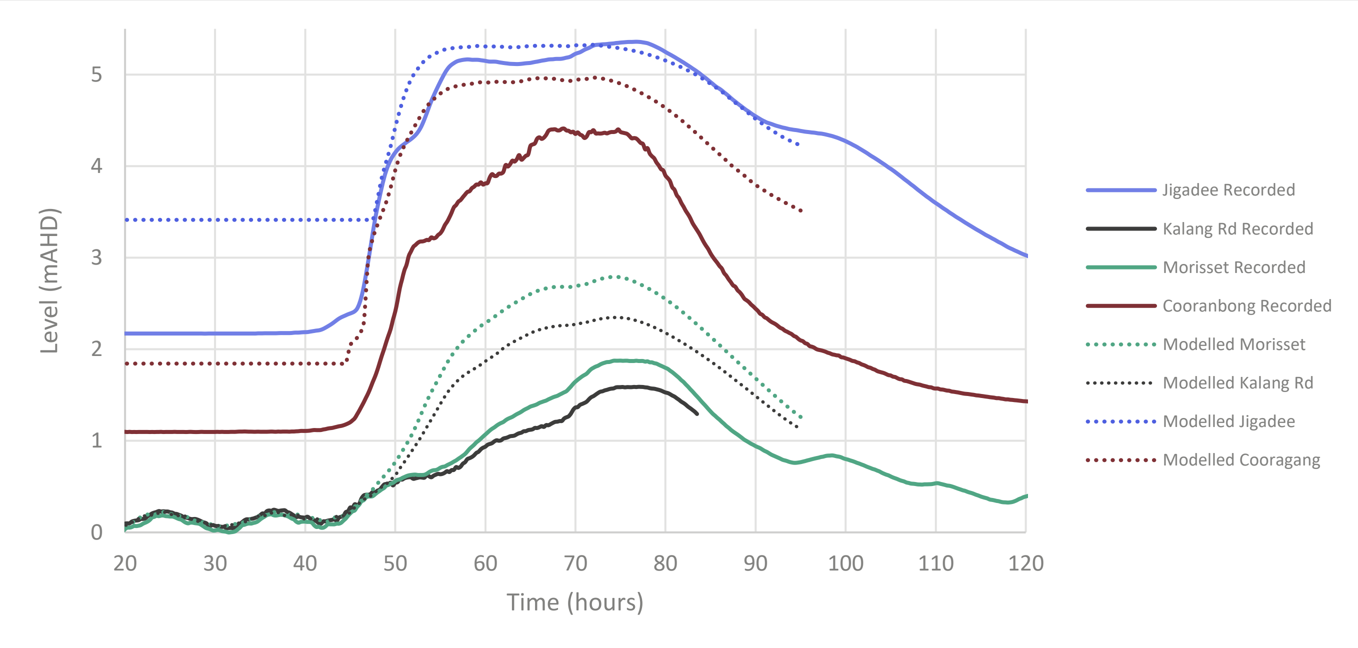

FIGURE 5.7: 2015 EVENT – HYDRAULIC MODEL RESULTS (BEST WBNM PARAMETERS NOT FINAL CALIBRATION) – LEVEL (MAHD)

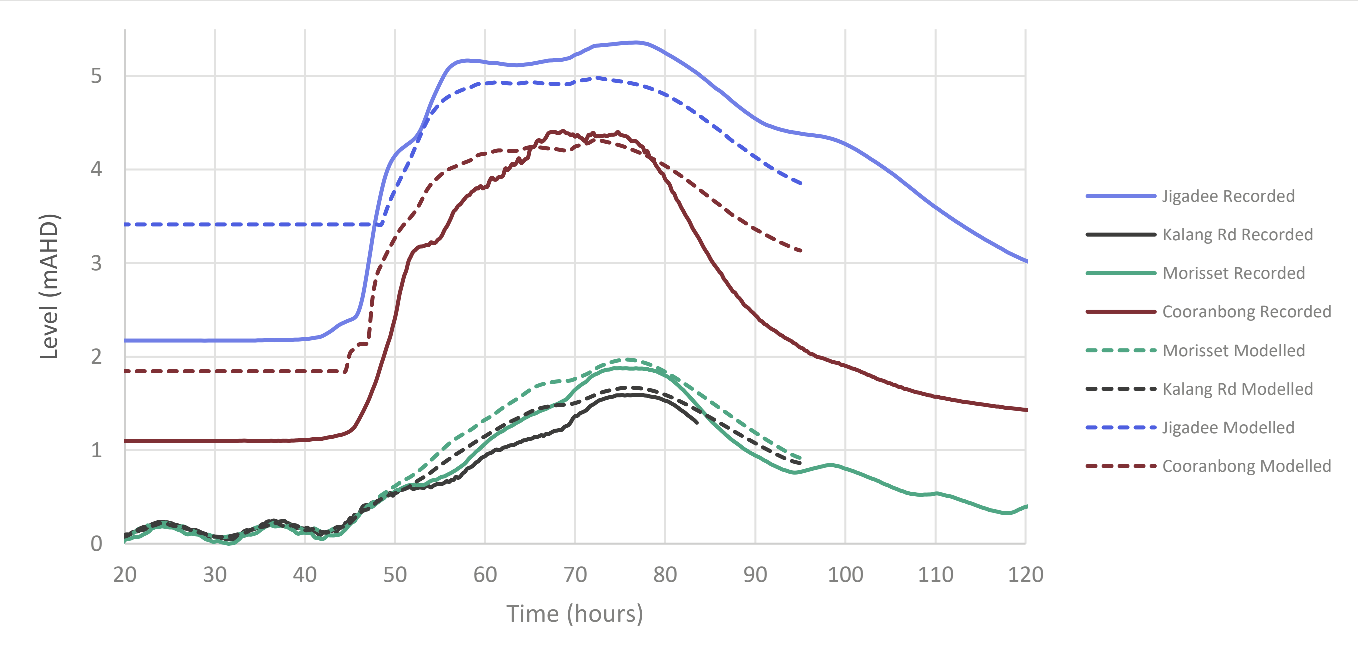

FIGURE 5.8: 2015 EVENT – FINAL CALIBRATION HYDRAULIC MODEL RESULTS – LEVEL (MAHD)

5.1.5 2022 Event

The 2022 event spanned over the period of a week, from the 1 July to the 7 July 2022.

As with the 2015 event, achieving a better match for hydraulic results was prioritised for model calibration. Figure 5.9 presents results for the calibrated parameters chosen for the 2022 event (refer to Table 5.1). A good responsiveness to the timing of peaks has been achieved, however, the modelled peak flow is lower than the recorded at 66.4 m^3/s compared to 116.7 m^3/s.

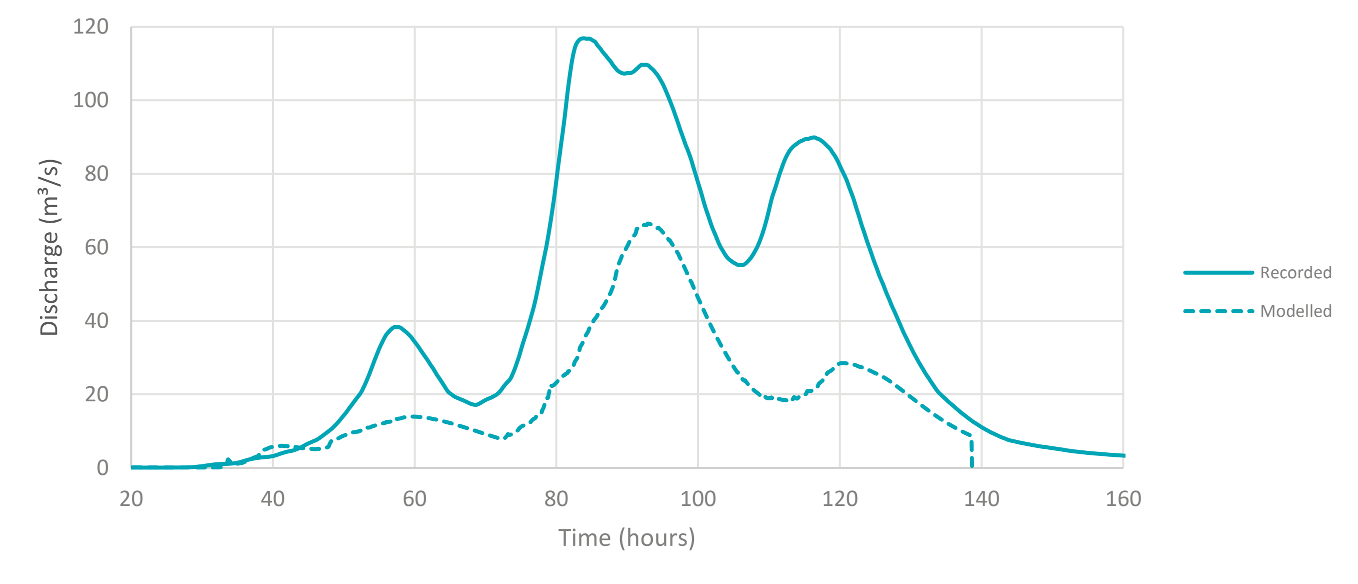

FIGURE 5.9: 2022 EVENT – HYDROLOGY MODEL RESULTS – FLOW (M^3/S)

Figure 5.10 presents a comparison of modelled (TUFLOW) and recorded levels at the available level gauges throughout the Dora Creek catchment for the final calibration results.

As with the hydrology results above, the hydraulic model results show a good responsiveness against the recorded timing of peaks and rising and falling limbs. The modelled peak levels for both the Jigadee and Cooranbong gauges are slightly lower than recorded, at 5.1 m compared to 5.3 m for Jigadee and 4.5 m compared to 5.1 m for Cooranbong. The modelled levels for both the Morisset and Kalang Road gauges are slightly higher than the recorded, at 2.2 m compared to the recorded 2.1 m at Morisset and 1.8 m compared to the recorded 1.7 m at Kalang Road. As such, a good calibration to the 2022 event has been achieved.

As with the other historical calibration events, the modelled starting levels do not align exactly to the recorded for the Jigadee and Cooranbong gauges due to location differences of the gauge position and results export location.

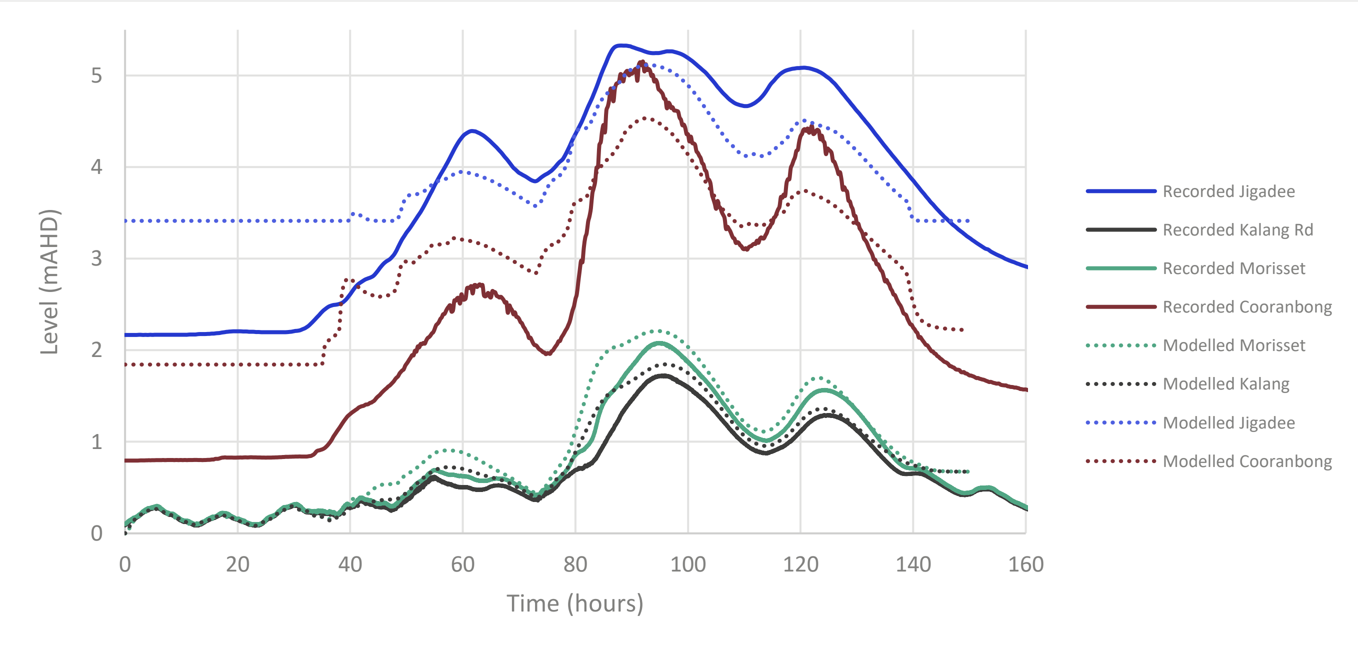

FIGURE 5.10: 2022 EVENT – HYDRAULIC MODEL RESULTS – LEVEL (MAHD)

5.2 Flood Frequency Analysis (FFA)

To validate the peak flows for design storm events from the hydrology model, a Flood Frequency Analysis (FFA) to the Jigadee gauge (WaterNSW gauge number 211008) was undertaken. This gauge was deemed suitable as it has 55 years of data available and is the only gauge in the catchment that records flow. The MHL gauges only record level and are tidally influenced so development of rating curves is not suitable, thus an FFA to these gauges could not be undertaken.

The validation to FFA was completed using the following methodology:

- Historical discharge results were exported from WaterNSW for the Jigadee gauge and yearly maximum flows (m^3/s) were determined, see Figure 5.13.
- Historical data was imported into RMC best fit and best fit distribution method was determined using the Bayesian analysis approach. The best fit for the data was Log Pearson Type 3, which had the lowest root mean square error of 4.5. Gumbel (EVI) distribution also showed a good fit for the data and had a root mean square error of 8.6. Both results are presented below.
- The hydrology model was iteratively run in storm injector with varied losses until the best match to FFA peak discharge (posterior predictive) was achieved. The peak discharge was taken from the critical duration results of the sub catchment (Jiga_05) located closest to the Jigadee gauge.
- The validated continuing and initial losses were then adopted for the AEP event runs, refer to Section 5.3.

Table 5.3 provides a summary predicted flows (m^3/s) from both of distribution methods against the final validated model flows at Jigadee gauge.

Figure 5.11 presents the results of the Gumbel distribution fit and Figure 5.12 presents the results of the Log Pearson Type 3 distribution fit. Both these figures show the posterior predictive, 5% confidence limit, and 95% confidence limit FFA results against the modelled peaks for each AEP event. For both distribution methods the same continuing and initial loss achieved the best match of modelled results to the FFA outputs (see Section 5.3).

TABLE 5.3: FFA PEAK DISCHARGE RESULTS COMPARISON

AEP Event (%)	Peak Discharge (m^3/s)		
	Log Pearson III	Gumbel	Validated Model
50	41.9	45.8	55.0
20	98.1	93.4	93.3
10	131.8	125.4	120.7
5	157.2	156.5	151.2
2	182.4	197.1	192.4
1	199.4	228.4	228.5

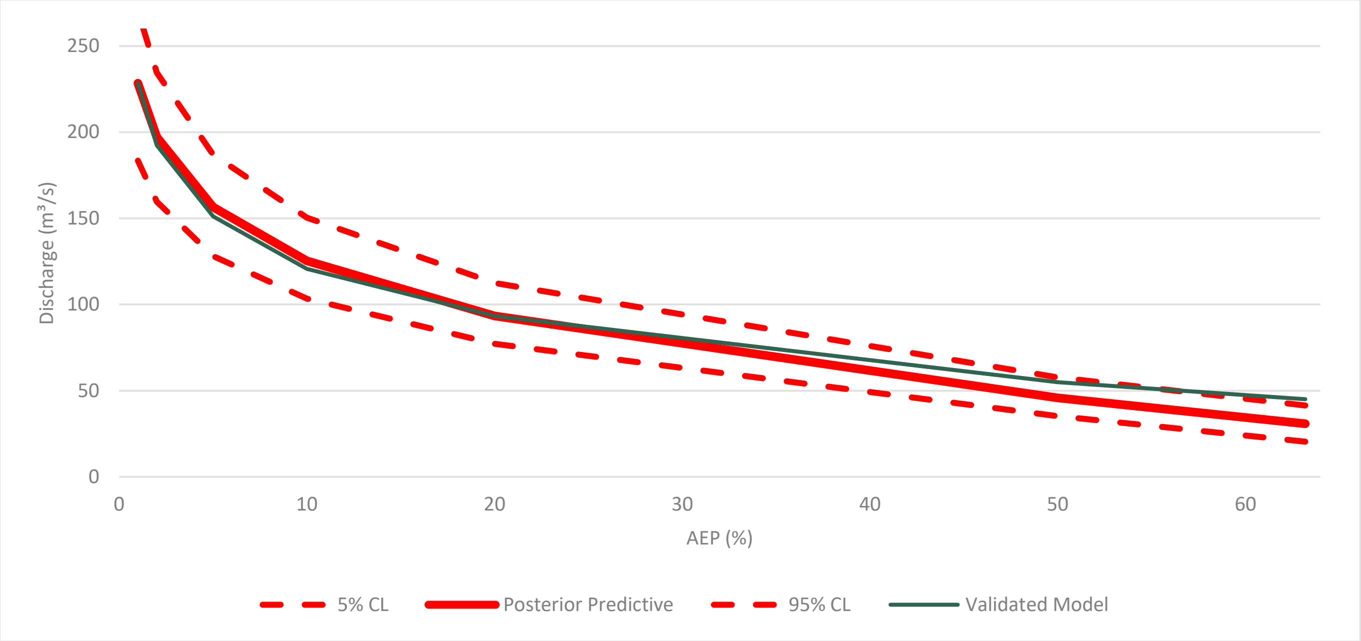

FIGURE 5.11: FFA RESULTS – MODELLED VS GUMBEL

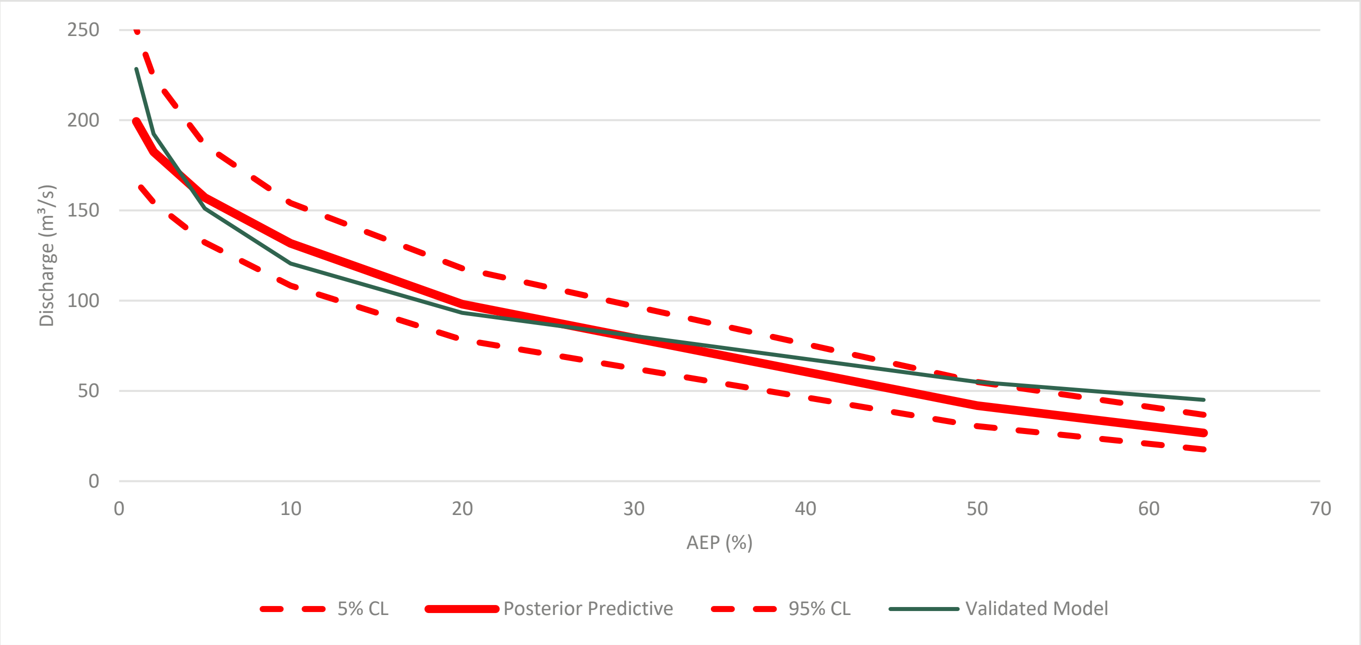

FIGURE 5.12: FFA RESULTS – MODELLED VS LOG PEARSON III (FINAL VALIDATION)

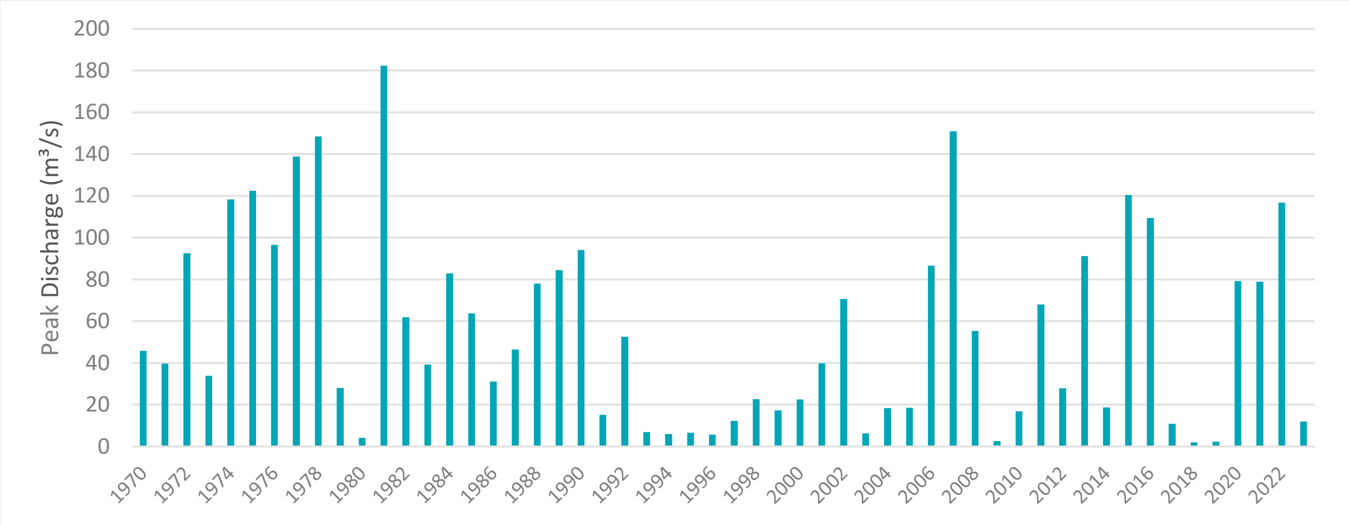

FIGURE 5.13: YEARLY PEAK DISCHARGES (M³/S) AT JIGADEE GAUGE

5.3 Verified Model Parameters

The final adopted hydrologic parameters for the AEP design events are presented in Table 5.4.

The pervious lag parameter was determined based on the average of the three most recent historical calibration results. The 1989 event was removed from this as it did not achieve as good a calibration as the other three events.

The initial and continuing losses were validated based on adjustment to match FFA analysis results.

TABLE 5.4: ADOPTED HYDROLOGIC MODEL PARAMETERS FOR DESIGN EVENTS

Parameter	Value
Pervious Lag Parameter	4.5
Initial Loss	6
Continuing Loss	1.25

6. DESIGN EVENT MODELLING

The calibrated model (Section 5) was used to estimate the flood response of the study area for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP and PMF flood events. While the focus of the discussion in this section is on the 1% AEP results, it is noted that Council's Development Control Plan also applies the 5% AEP and the PMF events for different land use applications. The 1% AEP flood is adopted here for discussion as it typically is most relevant to residential and commercial uses. The full suite of outputs are included in Appendix B. Appendix B also includes derived maps of flood hazard categorisation and velocity-depth product for each design event that can be used to inform consequences of flooding on the community (Section 7).

The sensitivity of the results to key model parameters, tailwater conditions, and rainfall intensities, have also been tested using the calibrated flood model. The focus of this sensitivity testing is on the 1% AEP flood event. The sensitivity of some parameters, such as Mannings roughness and rainfall losses, have been previously investigated as part of the calibration process (Section 5) and as such have been omitted from this discussion.

6.1 1% AEP flood event

The maximum modelled flood depths are included in Figure 6.1. shows that maximum modelled 1% AEP flood depths are expected to exceed one metre within some sections of existing residential and commercial areas, especially within the vicinity of Freemans Drive. The modelling indicates that for all events, the influence of Dora Creek is significant, typically extending to upstream of the Freemans Drive bridge for minor events (e.g. Figure B.1, in Appendix B), with the potential influence extending up to the M1 Motorway bridge (Figure 6.1). West of the M1 Motorway, Mandalong Road acts as a significant barrier to flood flows (Figure 6.1) for all modelled events.

Refer to Appendix B, Figure B.21 to Figure B.24 for all 1% AEP flood model result.

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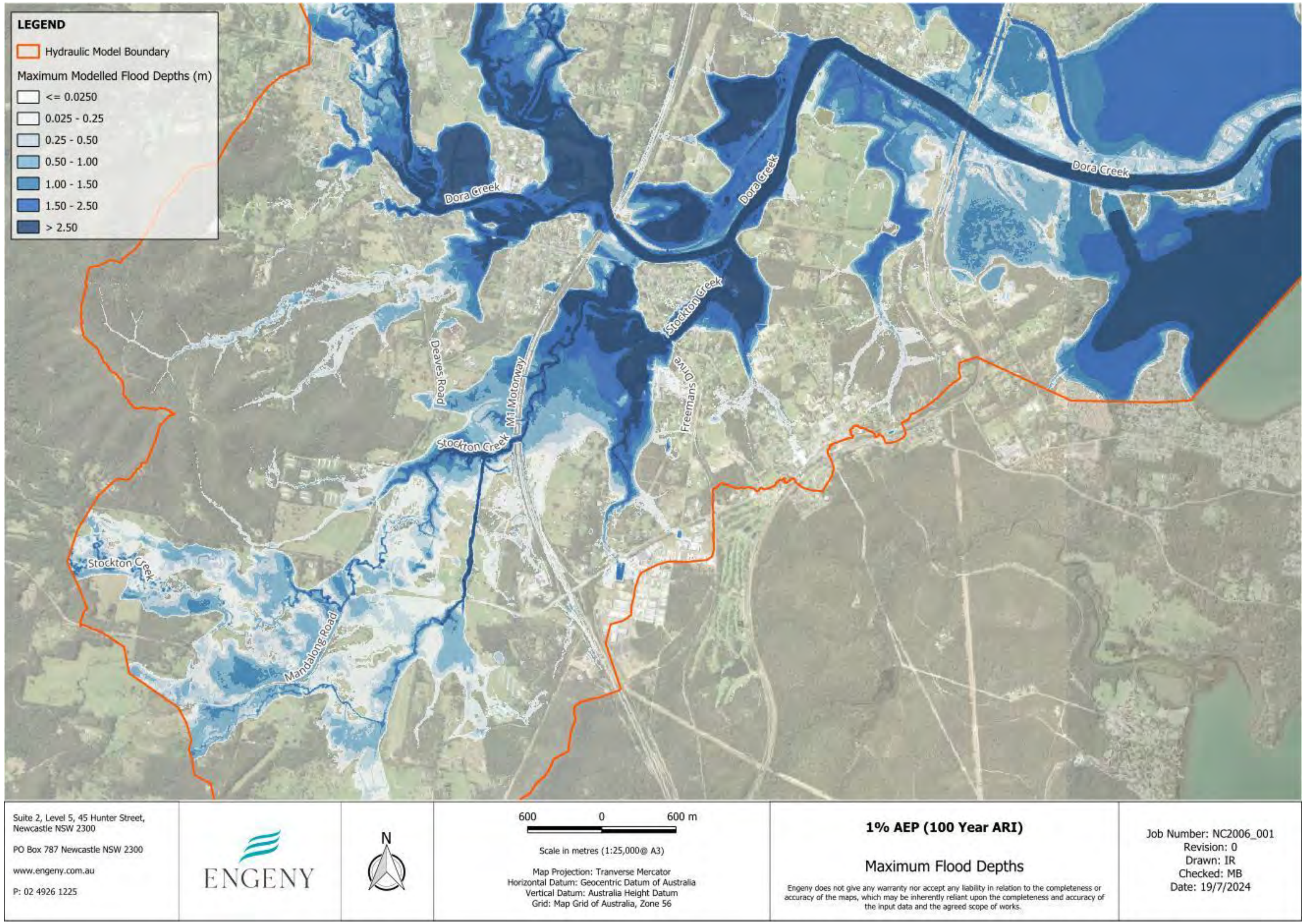

FIGURE 6.1: MAXIMUM MODELLED FLOOD DEPTHS – 1% AEP EVENT

6.2 Climate Change Analysis

To assess the impact of climate change (Section 2.3) from potential sea level rise, and increased rainfall intensity, four scenarios were modelled for the 1% AEP event as follows:

- Rainfall intensity varied by ±25%.
- Downstream boundary variation for sea level rise by 0.5m and 0.9m.

The scenarios were run in isolation in order to isolate the driver of the increase, and to determine the magnitude of the risk from either sea level rise, or rainfall intensity increase.

6.2.1 Climate Change

6.2.1.1 Sea Level Rise

Two sea level rise sensitivity scenarios were considered to assess the potential future climate change impacts; one with 0.5m and one with 0.9m sea level rise. These scenarios were simulated for the 1% AEP event and compared to the baseline results (Figure 6.1). Figure 6.2 and Figure 6.3 present the 0.5m and 0.9m sea level rise afflux results, respectively. Further modelling results for these scenarios can be observed in Appendix C, Figure C.8 to Figure C.16.

The afflux results indicate that that sea level rise has:

- *For the 0.5m scenario* **–** Minor increase to flood levels within Stockton Creek between the M1 and the Dora Creek confluence of between 0.02 and 0.04 m. The increase in depth is mainly contained within the Dora Creek, downstream of the rail bridge.
- *For the 0.9m scenario* – An increase in flood levels of up to 0.09 m in Stockton Creek between the M1 and the confluence with Dora Creek. There is a modelled impact of up to 0.14 m along Melaleuca Creek.

Tail water levels considered in Section 4.2.4 align with sea level rise scenarios (plus 0.5 m and plus 0.9 m).

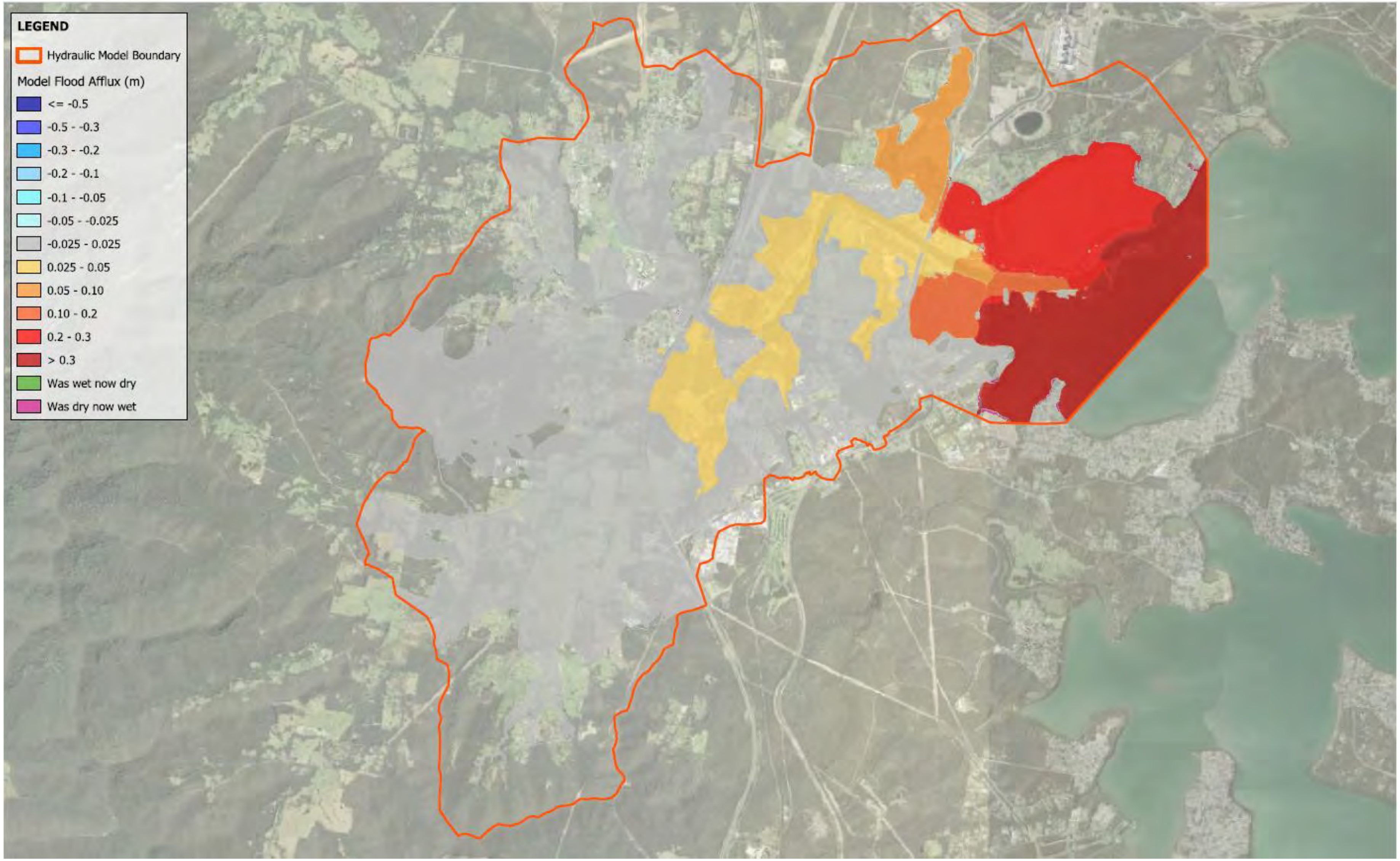

FIGURE 6.2: AFFLUX –SEA LEVEL RISE (0.5M) VS BASELINE – 1% AEP EVENT (100 YEAR ARI)

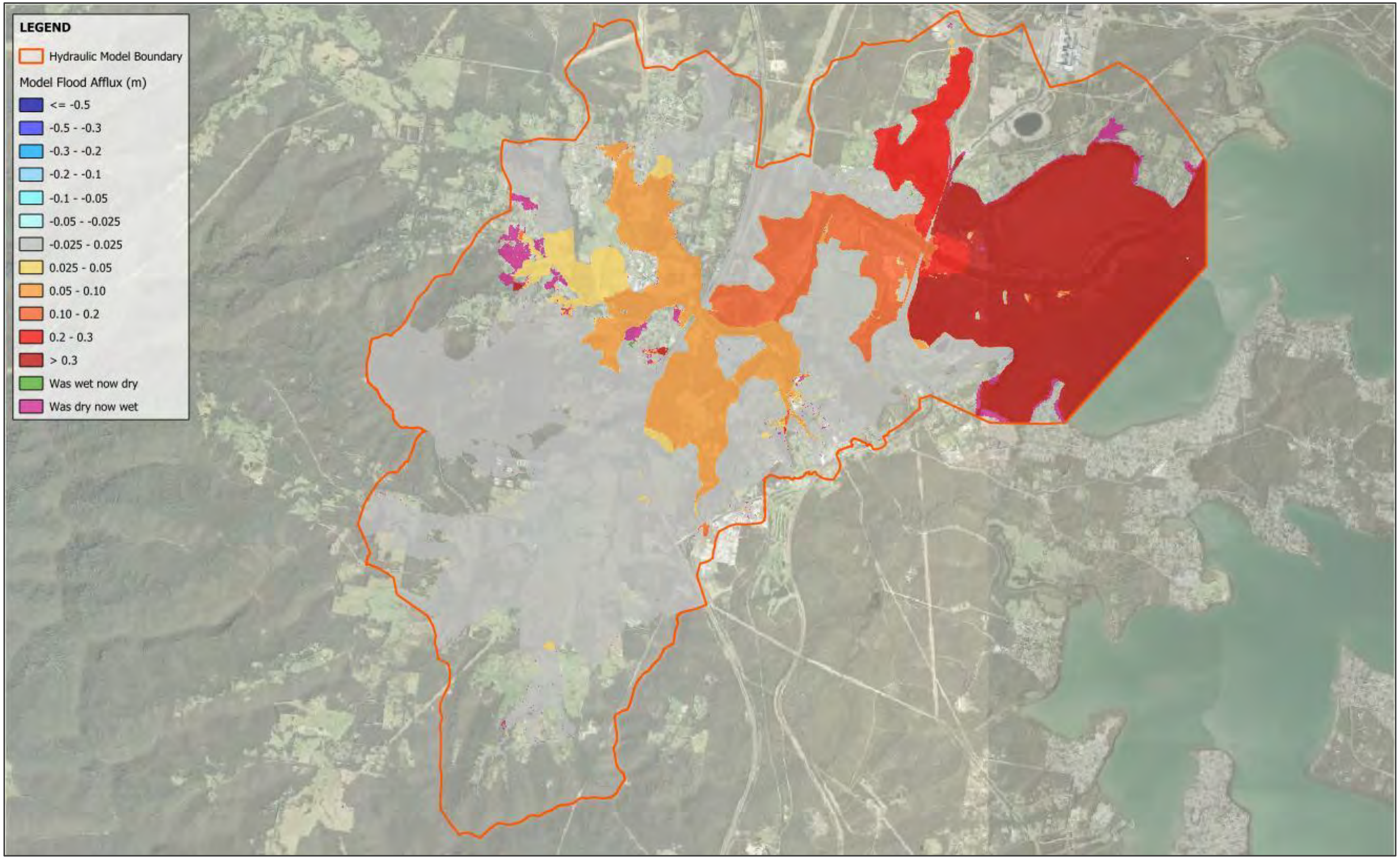

FIGURE 6.3: AFFLUX –SEA LEVEL RISE (0.9M) VS BASELINE – 1% AEP EVENT (100 YEAR ARI)

6.2.1.2 Increased Rainfall Intensity

Two rainfall sensitivity scenarios were considered to assess the potential future climate change impacts on rainfall intensity:

- 10% increase in rainfall intensity / storm volume; and
- 20% increase in rainfall intensity / storm volume.

Comparisons of the maximum modelled flood depths for the 1% AEP event to the baseline event (figure 6.1) for these two scenarios is included in Figure 6.4 and Figure 6.5 respectively.

The modelling indicates that a 10% increase in rainfall increases the 1% AEP flood depths upstream from the Dora Creek Bridge to the M1 Motorway, affecting larges areas of Morisset and the surrounding area (Figure 6.4). Modelled flood levels between the M1 and Freemans Drive typically see an increase of up to 0.27 m, while levels from Freemans Drive to the Confluence with Dora Creek see an increase of approximately 0.25 m. Flood levels within Melaleuca Creek are typically increased by up to 0.2 m.

A 20% increase in rainfall further extends these impacts (refer to (Figure 6.5), with modelled flood levels between the M1 and Freemans Drive typically see an increase of up to 0.45 m, while levels from Freemans Drive to the Confluence with Dora Creek see an increase of approximately 0.4 m. Flood levels within Melaleuca Creek are typically increased by up to 0.28 m.

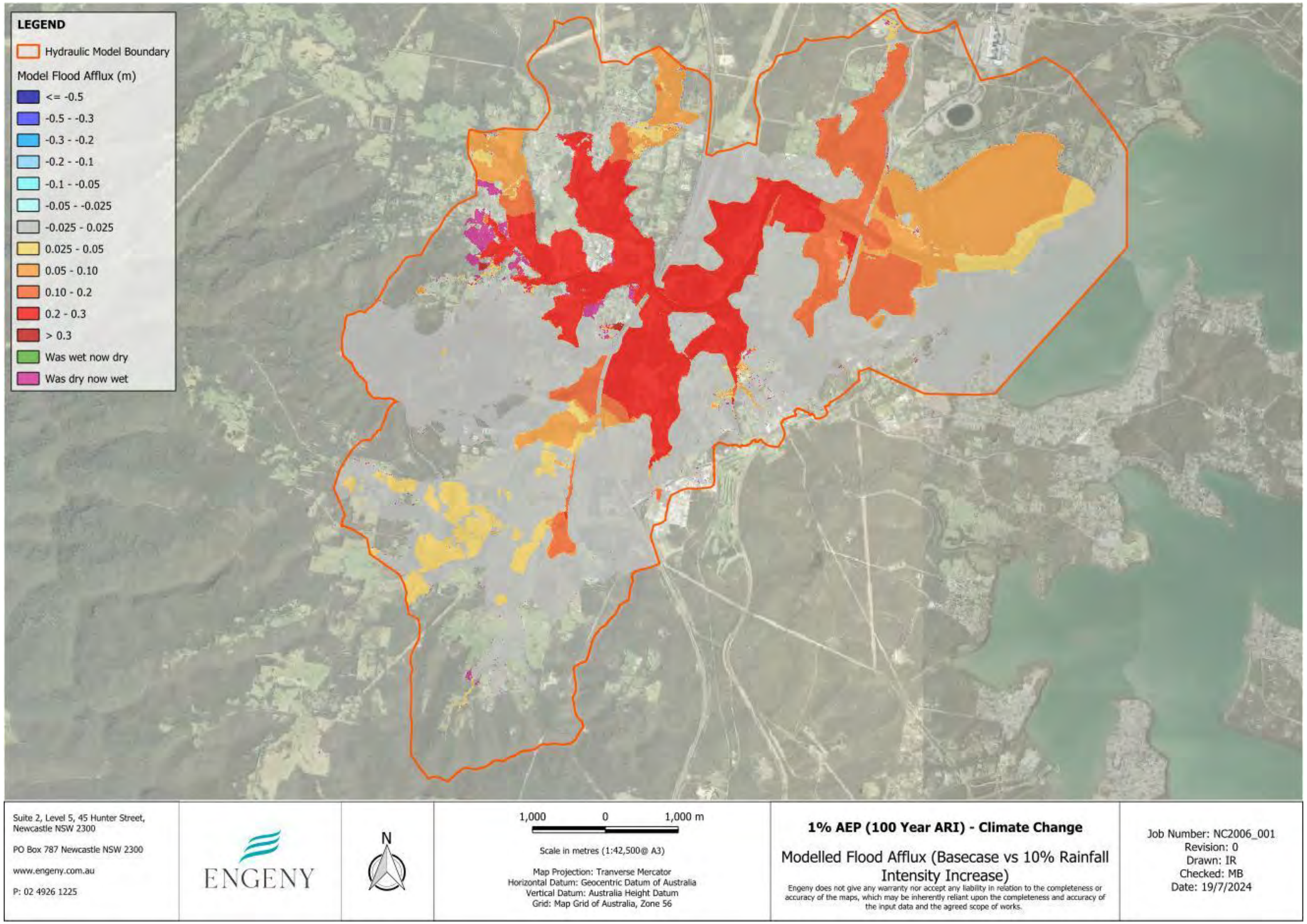

FIGURE 6.4: AFFLUX –10% RAINFALL INCREASE VS BASELINE - 1% AEP EVENT (100 YEAR ARI)

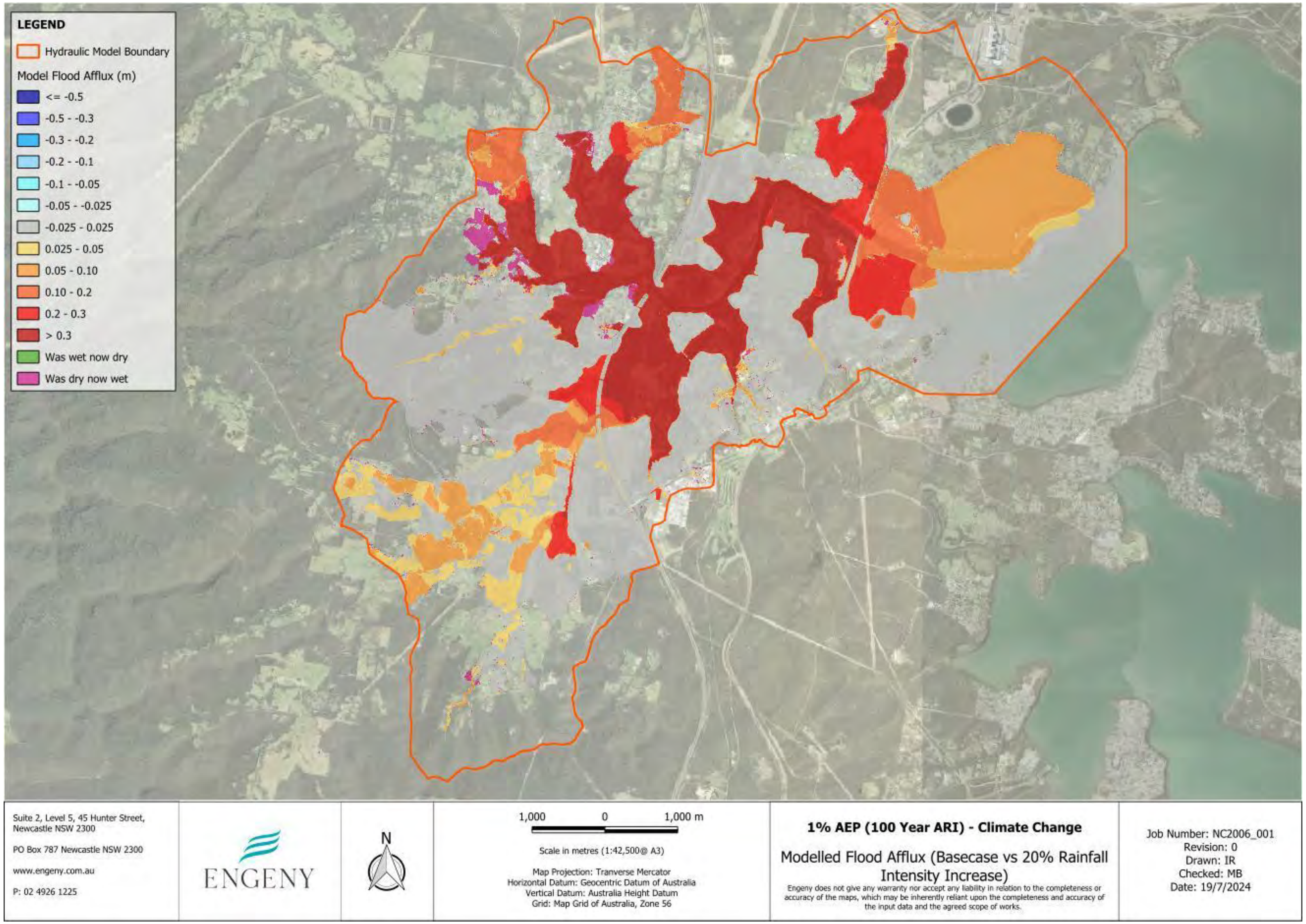

FIGURE 6.5: AFFLUX –20% RAINFALL INCREASE VS BASELINE - 1% AEP EVENT (100 YEAR ARI)

6.3 Sensitivity Analysis

To gain an understanding of sensitivity of the model to varying model parameters, an analysis was undertaken for the 1% AEP event. The following sensitivity analyses have been undertaken and are presented in the following sections:

- Blockage of pipes/bridges/culverts as per ARR19 guidelines.
- Mannings roughness varied by ±25%.
- Downstream model boundaries variation.

6.3.1 Blockage of Pipes/ Bridges/ Culverts

A blockage scenario with blockages applied as per Book 6, Chapter 6 of ARR 2019 guidelines has been assessed and compared to the baseline results. Figure 6.6 presents the 1% AEP afflux results for this scenario against the baseline, further mapping is presented in Appendix C (Figure C.17 to Figure C.20).

Blockage of culverts and bridges using the ARR 2019 guideline method has resulted in minimal impacts to the overfall 1% AEP depth results. However, results do generally show increased retention of flood waters upslope of the structures ('was dry now wet' areas on Figure 6.6), which in turn results in increased depth and extent of overflows of existing roads. This would reduce the accessibility during large flood events. The bridge furthest to the north along the M1 Motorway has been impacted the most by blockages, with depth increases of between 0.2 – 0.4 m. However, whilst this increase is within the modelled extent, it is outside the study area.

6.3.2 Mannings Roughness

Increasing the Mannings roughness by 25% results in a general increase in flood depths of up to 0.3 m within areas within the floodplain (Figure 6.7), as the increased roughness slows the flow of flood flows through the system. Conversely, reducing the Mannings roughness by 25% results in a general decrease in flood levels of up to 0.3 m within the floodplain (Figure 6.8).

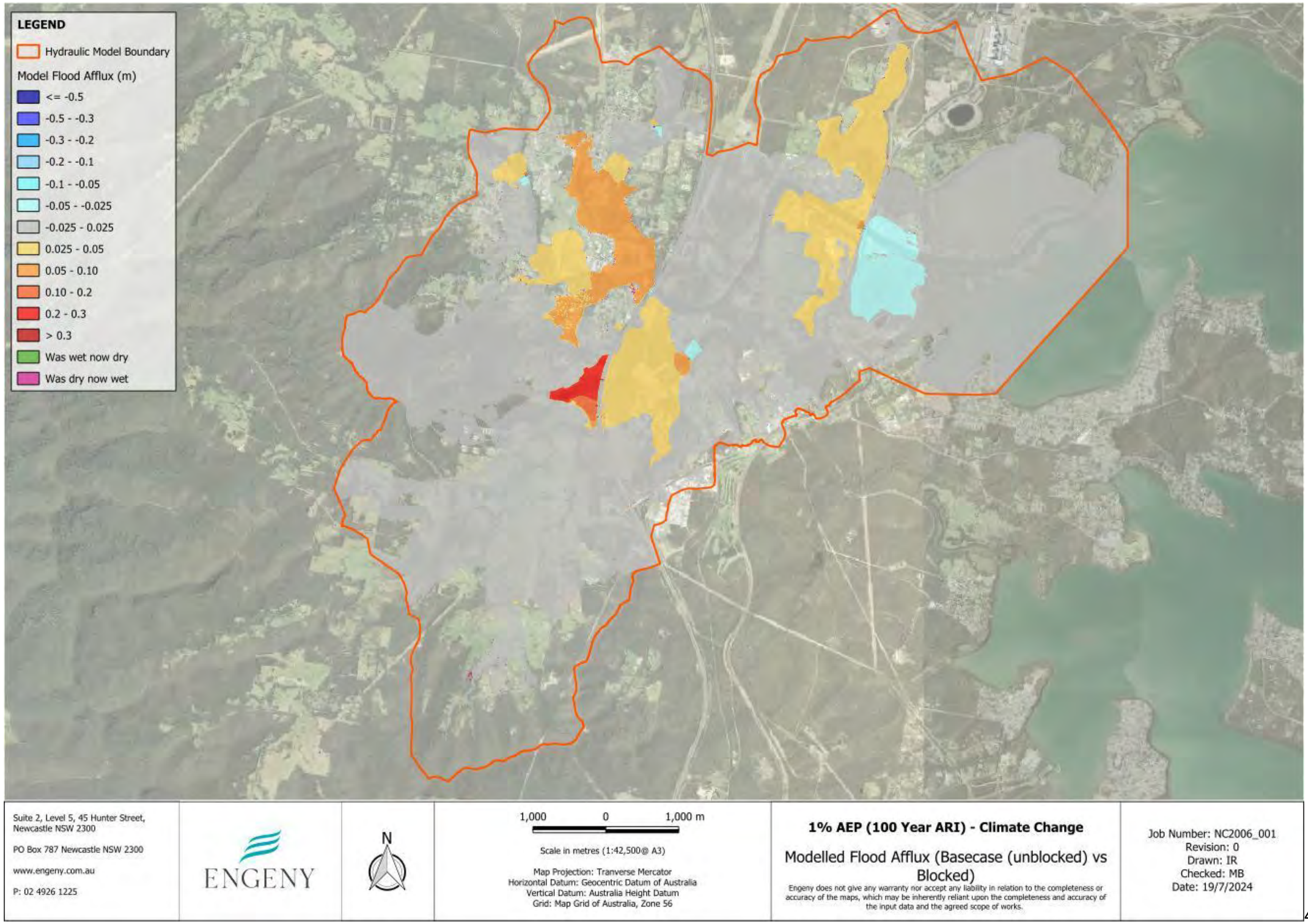

FIGURE 6.6: AFFLUX – BLOCKAGE VS BASELINE (NO BLOCKAGE)

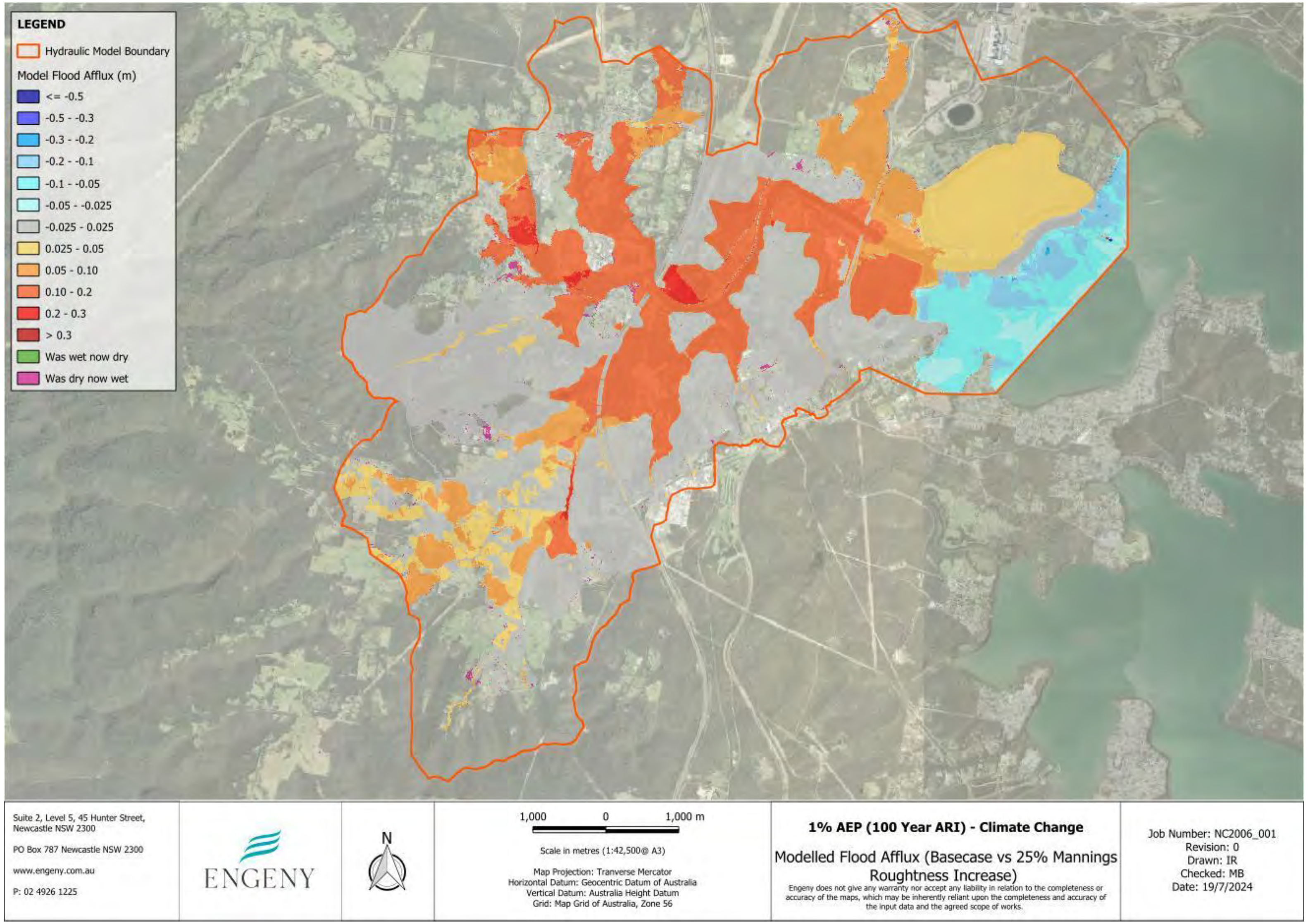

FIGURE 6.7: AFFLUX –25% MANNINGS ROUGNESS INCREASE VS BASELINE - 1% AEP EVENT (100 YEAR ARI)

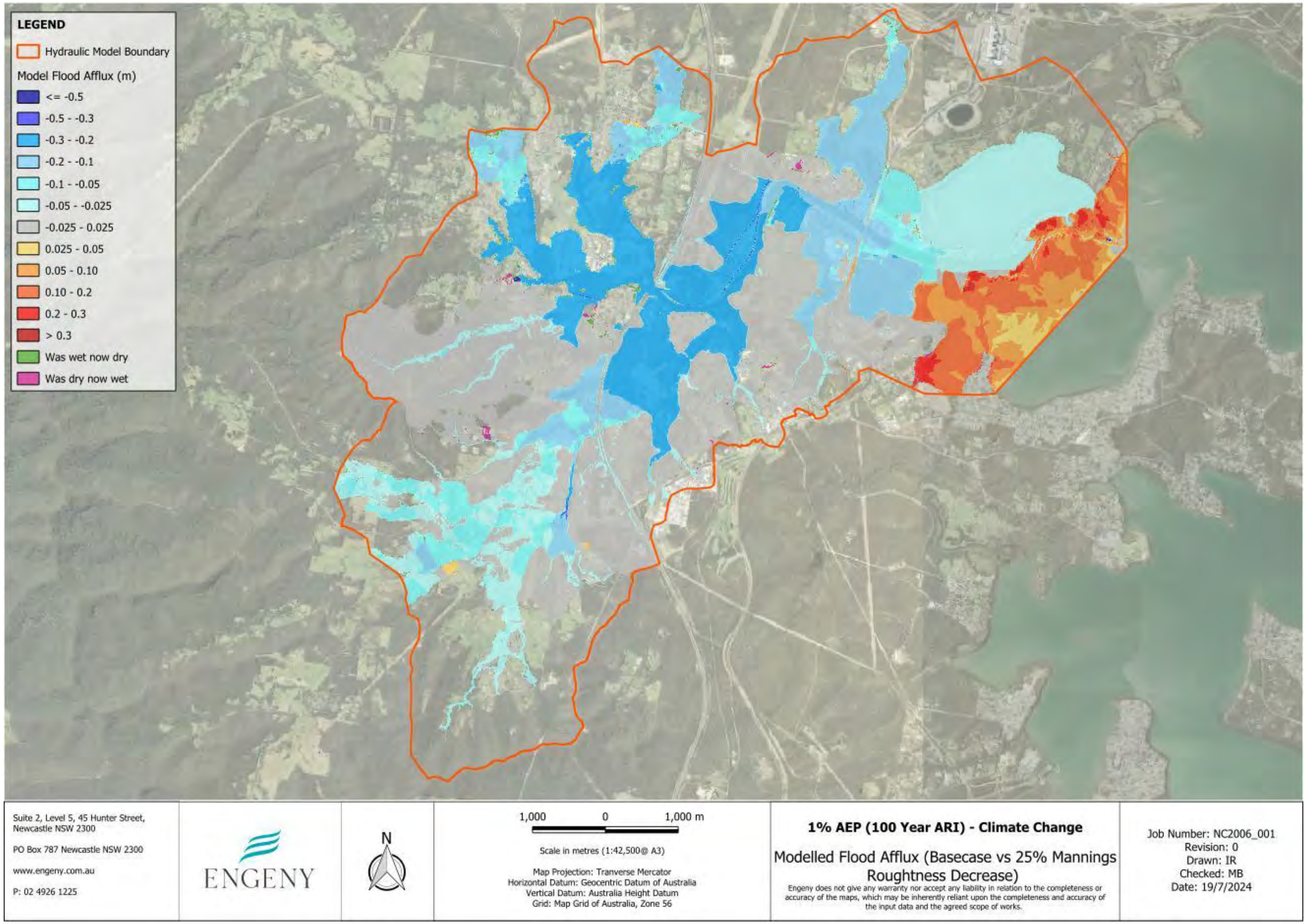

FIGURE 6.8: AFFLUX –25% MANNINGS ROUGNESS DECREASE VS BASELINE - 1% AEP EVENT (100 YEAR ARI)

7. CONSEQUENCES OF FLOODING ON THE COMMUNITY

Flood hazard, flood function, flood planning area, and flood emergency response classification have been developed to to support Council in determining potential future land use planning and development controls. Description of the approaches to the mapping and the subsequent delineations are discussed in the following sections.

7.1 Flood Hazard

Flood hazard maps have been prepared in accordance with ARR 2019 and the Floodplain Risk Management Manual (DPE 2023) (Section 2.3) for each design storm event modelled and included in Appendix B.

Flood hazard is a measure of the potential hazard presented by a flood event to people, vehicles, and buildings. It uses a combination of modelled flood depths and velocities to classify points within the floodplain into six categories (Figure 7.1).

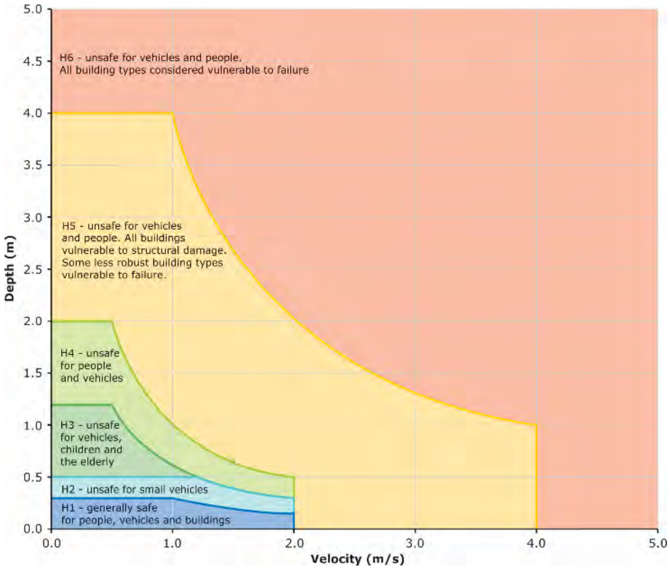

FIGURE 7.1: COMBINED FLOOD HAZARD CURVES (FROM ARR 2019).

The maximum modelled flood hazards for the 1% AEP flood event are included in Figure 7.2. The following was observed regarding the 1% AEP flood hazard:

- The highest risk flows (H6) are constrained to the main channels, with other areas of high hazard (H4 and H5) typically adjacent to watercourses but outside of developed areas (Figure 7.2).
- Most residential areas are located with lower (H1 to H3) hazard areas.
- The majority of the study area west of the M1 typically ranges from H1 to H3.

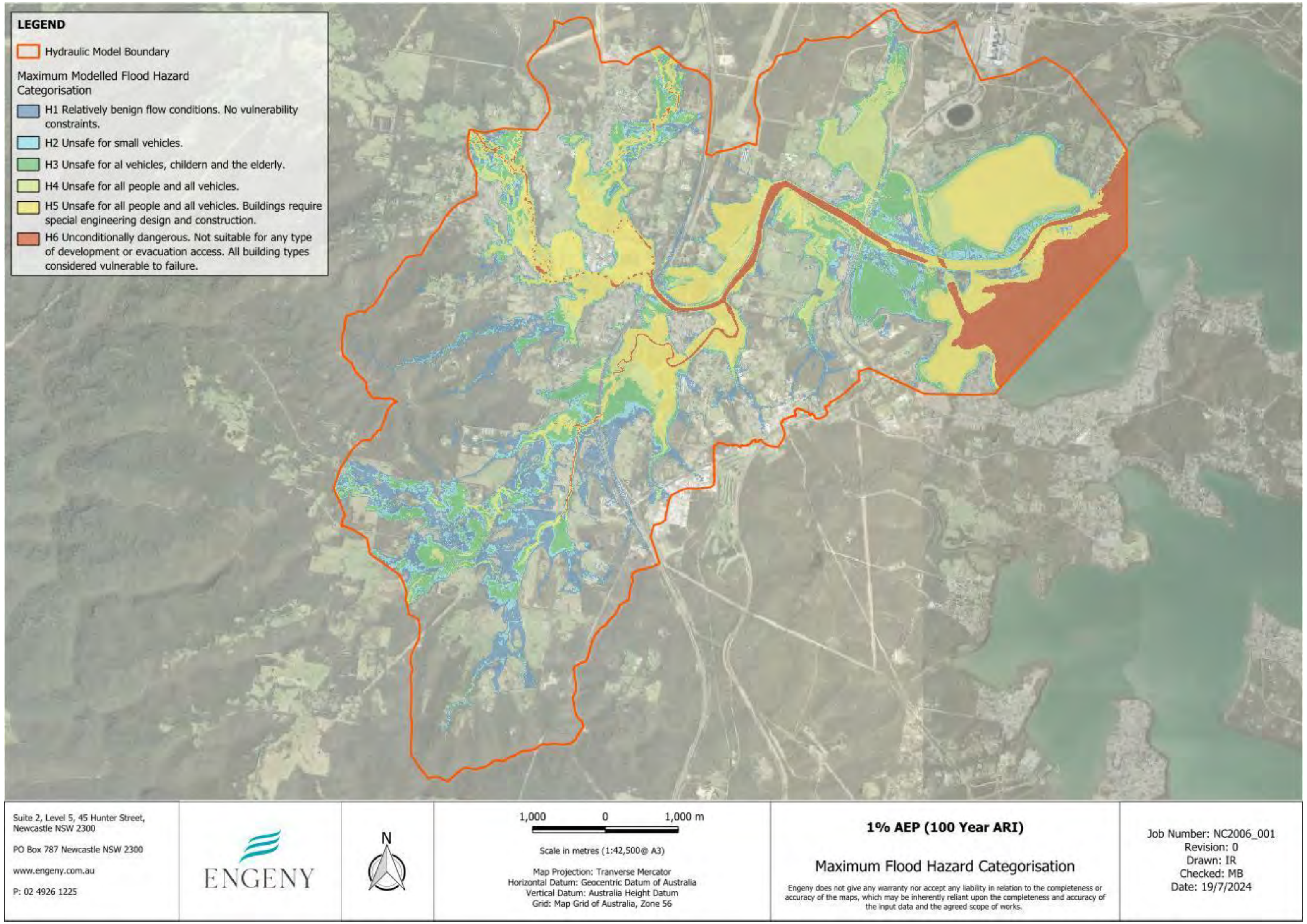

FIGURE 7.2: MAXIMUM MODELLED FLOOD HAZARD CATEGORISATION

7.2 Flood Function (Hydraulic Categorisation)

Flood function separates flood affected areas into:

- Floodway – areas which convey a significant portion of flood waters, typically watercourses but may include flood runners or overflow pathways. Floodways typically include deep, fast flowing water. Flood extents and depths are highly sensitive to development within the floodway.
- Flood storage – areas adjacent to floodways, which temporarily store flood waters. Flood storages areas typical include shallower slower moving, or back-flowing waters. Flood extents and depths are somewhat sensitive to development within flood storage areas, principally due to the loss of storage capacity within the floodplain.
- Flood fringe – all other flood affected areas. Development within flood fringe areas typical results in minimal impacts to flood extents and depths.

Flood function has been delineated for the modelled area using *Flood Risk Management Guide FB02: Flood Function* (NSW Department of Planning and Environment 2022).

The following general area classifications have resulted from the flood function mapping activities:

- Floodway areas generally align with locations where the 1% AEP depth x velocity (DxV) results exceed 0.45 m^2/s in the latest hydraulic modelling results. The main channel and a portion of the floodplain of Dora Creek and Stockton Creek all fall within this classification.
- Flood storage areas generally align with locations where low velocity (less than 0.5 m/s) water is stored at depth greater than 1 m in the 1% AEP event. Flood storage areas were largely identified in Stockton Creek between the M1 and Freemans Drive, and downstream of Freemans Drive to the confluence with Dora Creek.
- Flood fringe classifications estimation has been applied to all remaining areas within the flood extent and include localised areas on the edge of the flood extent not included under the floodway or flood storage classifications.

The flood function mapping has been prepared and provided in Figure 7.3.

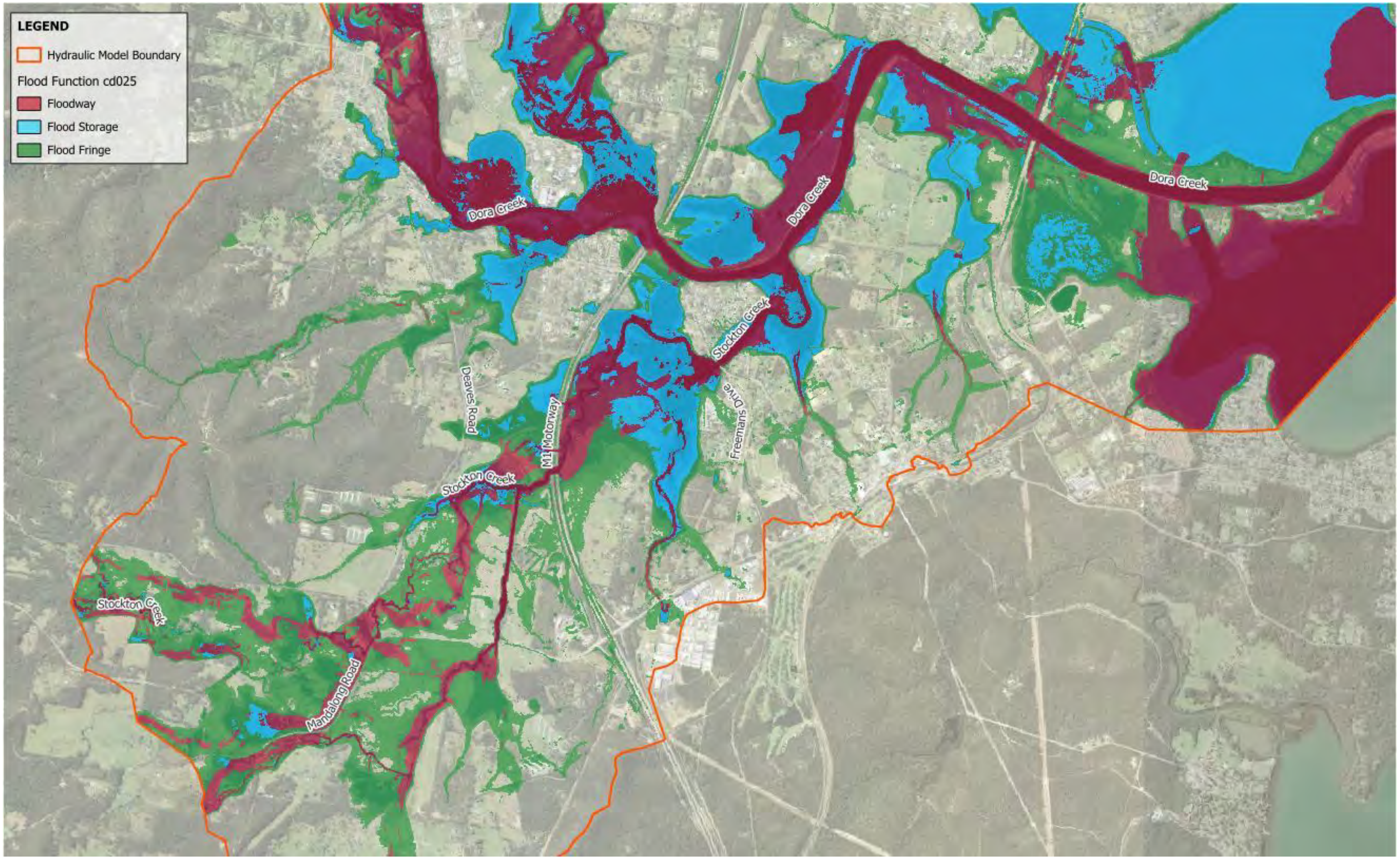

FIGURE 7.3: FLOOD FUNCTION MAPPING

7.3 Flood Emergency Response Classification of Communities

Flood emergency response classification divides the flood affected area into sub-areas of increasing risk with respect to emergency management. These classifications consider both flood dynamics (depth, velocity, and duration) as well as emergency access and egress. Higher risk areas include flood islands, which remain flood free but do not have safe access during flood events, preventing emergency services from accessing the areas via standard methods.

The flood emergency response classification has been prepared and presented in Table 7.1.

TABLE 7.1: FLOOD EMERGENCY RESPONSE CLASSIFICATIONS

Flood Emergency Response Classification	Description
High Flood Island	Areas suitable for refuge remain flood free in the PMF. Evacuation is not practical prior to flooding and resupply by boat or air will be required until access is reinstated.
High Trapped Perimeter Area	Areas suitable for refuge remain flood free in the PMF. Evacuation is not practical prior to flooding, however, the area is not completely surrounded by floodwater.
Low Flood Island	The area is flooded in a PMF event. Evacuation is not practical prior to flooding.
Low Trapped Perimeter Area	The area is flooded in a PMF event. Evacuation is not practical prior to flooding, however, the area is not completely surrounded by floodwater.
Areas with Rising Road Access	The area is flooded in a PMF event. Evacuation is practical prior to flooding, with access to a road that rises continually out of the PMF.
Areas with Overland Escape Route	The area is flooded in a PMF event. Evacuation is practical prior to flooding, via overland means on foot.

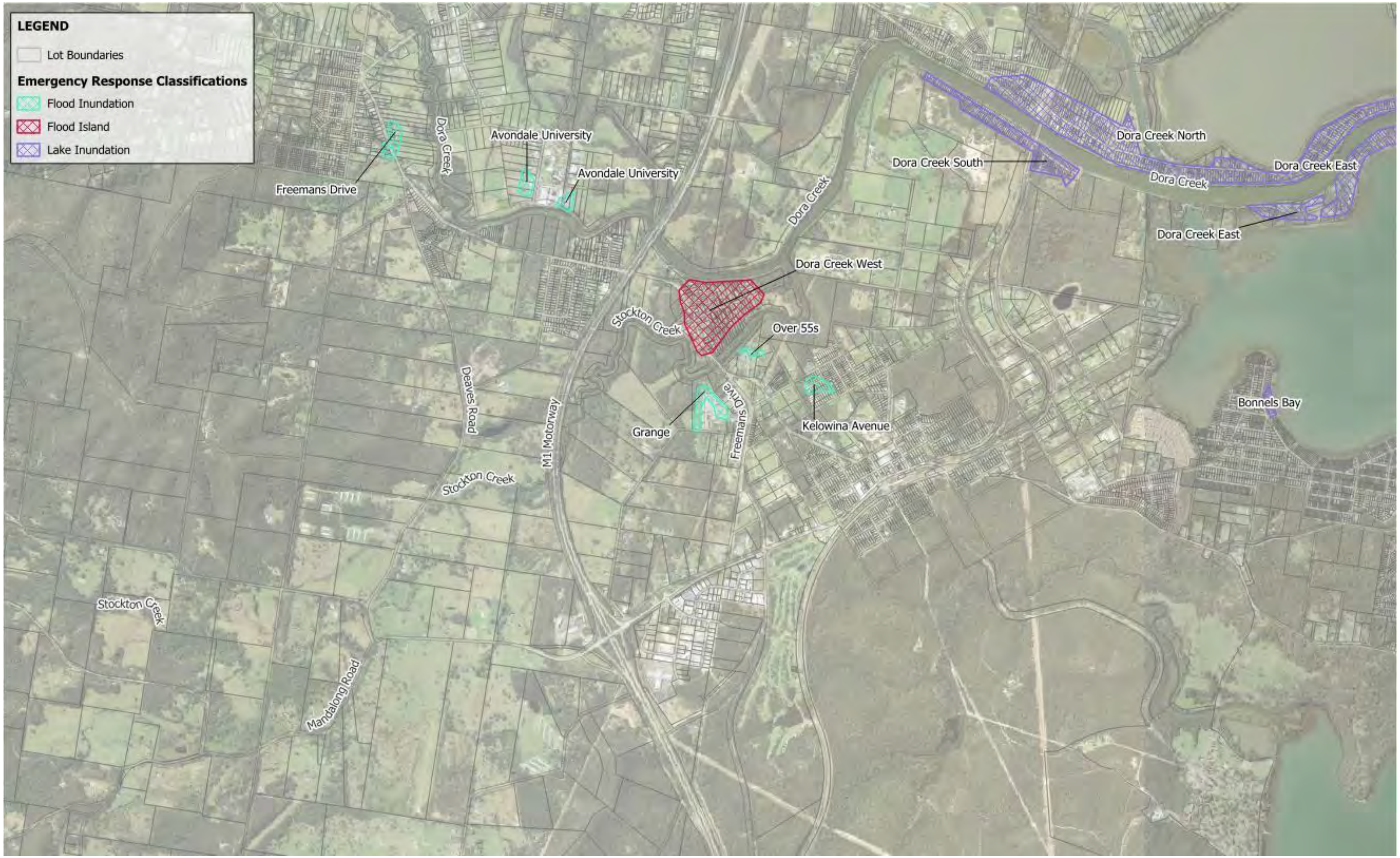

FIGURE 7.4:FLOOD EMERGENCY RESPONSE CLASSIFICATION

7.3.1 Flood Islands

Two flood islands have been identified: one adjacent to Dora Creek and one at Avondale.

The Dora Creek flood island (Figure 7.5) has been identified as a High Flood Island and is therefore generally located above the modelled PMF level. Evacuation from "Dora Creek West" should be undertaken early via Freemans Drive, if at all. During large flood events, once flooded it is expected that this area will remain isolated for several days.

The Avondale flood island is a low flood island, being above the maximum modelled 1% AEP flood level, but inundated during the PMF event (Figure 7.6). Evacuation of this area via Freemans Drive is to be undertaken as early as possible.

FIGURE 7.5: DORA CREEK WEST HIGH FLOOD ISLAND

FIGURE 7.6: AVONDALE LOW FLOOD ISLAND

7.4 Consequences of Flooding on People

An assessment of the consequences of flooding on people, economy, environment, public administration and social setting has been assessed for a range of design flood events. This assessment has been based on historical and anecdotal information, in addition to model results and relevant mapping for key design events. As noted in Section 7.5.1, no floor level information was available and instead estimated according to the construction type.

This assessment has included a review of the following:

- Property subject to inundation and risk to life.
- Community and emergency facilities subject to inundation.
- Inundation of key road crossings.

Table 7.2 shows the total number of properties, commercial, and community buildings inundated for each modelled AEP event. These have been identified using GIS as buildings located within the modelled flood extents. As expected, the number of affected properties generally increases with the flood magnitude, however the number of commercial and community properties affected by flooding peaks at around the 2% AEP event, until the PMF.

Key roads and the inundation in the 1% AEP and PMF events are shown in Table 7.3. Each of these locations is unsafe for vehicles (hazard category 3 or higher) for the 1% AEP event, making evacuation by road during a 1% AEP event (or above) very dangerous.

TABLE 7.2: PROPERTIES SUBJECT TO GROUND LEVEL INUNDATION

Type	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
Residential	132	179	212	240	276	301	326	762
Commercial	9	11	13	19	20	20	21	37
Community	14	17	18	19	19	19	19	30
Total	**155**	**207**	**243**	**278**	**315**	**340**	**366**	**829**

FIGURE 7.7: BUILDINGS AND KEY ROADS INUNDATED FOR DESIGN FLOOD EVENTS

TABLE 7.3: KEY ROADS INUNDATED

Road Name	Peak Depth –1%	Peak Flood Hazard Categorisation – 1%	Peak Depth - PMF	Peak Flood Hazard Categorisation – PMF
Mandalong Road	0.2 m	4	0.9 m	5
Freemans Drive at Stockton Creek	0.1 m	3	4.5 m	6
Freemans Drive at M1	1.0 m	5	6.3 m	6
Deaves Road	0.4 m	5	1.0 m	6
Gimberts Road	1.9 m	5	5.8 m	6

**As labelled in Figure 7.7*

7.5 Flood Damages Assessment

An estimation of the direct tangible damages and annual average damage (AAD) has been completed for the study. The flood damages assessment has been based on the publicly accessible Bing Maps countrywide properties polygons, and utilising the NSW Department of Planning and Environment's (DPE) latest Flood Damage Tool spreadsheet as detailed in *Flood Risk Management Measures: Flood Risk Management Guide* (NSW DPE, 2022).

The flood damage assessment has determined:

- Number of properties which are flood affected and their category.
- The tangible damages.
- Average Annual Damage (AAD).

7.5.1 Input Data and Damage Curves

To undertake a flood damage assessment, the following GIS data inputs were used:

- Building polygons / assumed floor size of building.
- Floor levels.
- Classification of the type of building and number of storeys.

The following process was undertaken to prepare the GIS dataset for the flood damage assessment:

(1) Delineation of all building polygons within the study area. Initially, building polygons sourced from the Bing Maps countrywide properties dataset were used where possible, with gaps filled by the manual delineation of any remaining buildings observed in the aerial.

(2) Calculation of the floor area using geometry analysis tools.

(3) Classification of the various buildings as either 'slab on ground', 'on short stumps', or 'on high stumps'.

(4) Classification of the various buildings into the Property Types specified in the Flood Damage Tool. Where there was a lack of information about specific commercial uses, the default average (type 7) were selected for commercial/industrial uses.

(5) No floor level survey was available to apply ground and floor levels to the buildings so the ground level was determined by inspecting the average topographical level from the 2014 1m LiDAR dataset underneath the footprint, and the floor level was determined adding the following additional height to the ground level:

    (a) 150 mm for 'slab on ground'.

    (b) 500 mm for 'on short stumps'.

(c) 1500 mm for 'on high stumps'.

Full details of the development, assumptions and limitations of the damage curves utilised in the assessment are available in *Flood Risk Management Measures: Flood Risk Management Guide* (NSW DPE, 2022), and has not been repeated in this report. In summary, the flood damage assessment considers the following:

- Residential flood damages, comprising:
  - Structural damages.
  - Contents damage.
  - External damage.
  - Vehicles at home.
  - Relocation costs.
  - Clean up costs.
- Non-residential buildings:
  - Classification based damage costs.
  - Vehicles at work.
  - Loss of trading costs.
  - Clean up costs.
- Intangible damages:
  - Risk to life.

The following adjustments were made in the Flood Damage Tool to be specific to the Study Area:

- No regional cost adjustment factor was applied in accordance with Lismore being located in the Eastern Land Division, north of Newcastle.
- The latest available Average Weekly Earnings and Consumer Price Index values were updated to Q3 2024 in accordance with the Australian Bureau of Statistics data.

7.5.2 Flood Damages Assessment

Average Annual Damage (AAD) is used to account for the probabilistic nature of flood damage. It represents the theoretical tangible damage incurred on average each year if a very long period of flood records is considered. It takes into account the value of the damage in each flood and the probability of the flood.

The flood damage assessment was completed for the modelled design events, with the following damage estimates able to be provided:

- Table 7.3: Key Roads Inundated
- Table 7.4: Residential Damage Disbenefits and Cost Summary
- Table 7.5: Commercial/ Industrial and Public Building Damage Disbenefits And Costs Summary
- Table 7.6: Other Disbenefits and Costs Summary (other negative impacts associated with flooding)

TABLE 7.4: RESIDENTIAL DAMAGE DISBENEFITS AND COST SUMMARY

Event	No. of properties flooded above ground	No. of properties flooded above floor	Total Damages	Contribution to AAD total
PMF	762	735	$287,465,830	$894,374
0.5% AEP	326	302	$70,290,733	$330,562
1.0% AEP	301	277	$61,933,927	$578,549

Event	No. of properties flooded above ground	No. of properties flooded above floor	Total Damages	Contribution to AAD total
2% AEP	276	252	$53,775,919	$1,461,306
5% AEP	240	219	$43,644,511	$1,988,828
10% AEP	212	175	$35,908,609	$3,333,798
20% AEP	179	152	$30,767,346	$7,745,259
50% AEP	132	107	$20,867,713	$5,216,928
Total				**$21,549,604**

TABLE 7.5: COMMERCIAL/ INDUSTRIAL AND PUBLIC BUILDING DAMAGE DISBENEFITS AND COSTS SUMMARY

Event	No. of properties flooded above ground	Total Damages	Contribution to AAD total
PMF	35	$28,541,679	$144,412
0.5% AEP	17	$29,224,171	$147,018
1.0% AEP	17	$29,583,139	$286,411
2% AEP	17	$27,699,041	$811,346
5% AEP	14	$26,390,705	$989,615
10% AEP	10	$13,193,907	$1,441,435
20% AEP	9	$15,634,787	$3,031,166
50% AEP	7	$4,572,987	$1,143,247
Total			**$7,994,650**

TABLE 7.6: OTHER DISBENEFITS AND COSTS SUMMARY

Event	No. of injuries	No. of Fatalities	Contribution of Intangible damages to AAD total
PMF	107.84	7.43	$225,136
0.5% AEP	4.98	0.15	$20,896
1.0% AEP	3.43	0.10	$32,043
2% AEP	1.88	0.03	$79,676
5% AEP	0.81	0.01	$108,663
10% AEP	0.44	0.00	$145,352
20% AEP	0.17	0.00	$316,761
50% AEP	0.00	0.00	$256,824
Total			**$1,185,351**

Figure 7.8 shows the breakdown for each property category, and the relative contribution of each AEP to the AAD estimate. The result shows that the more frequent events (I.e. the 50% and 20% AEP events) account for almost 60% of the contribution to the AAD.

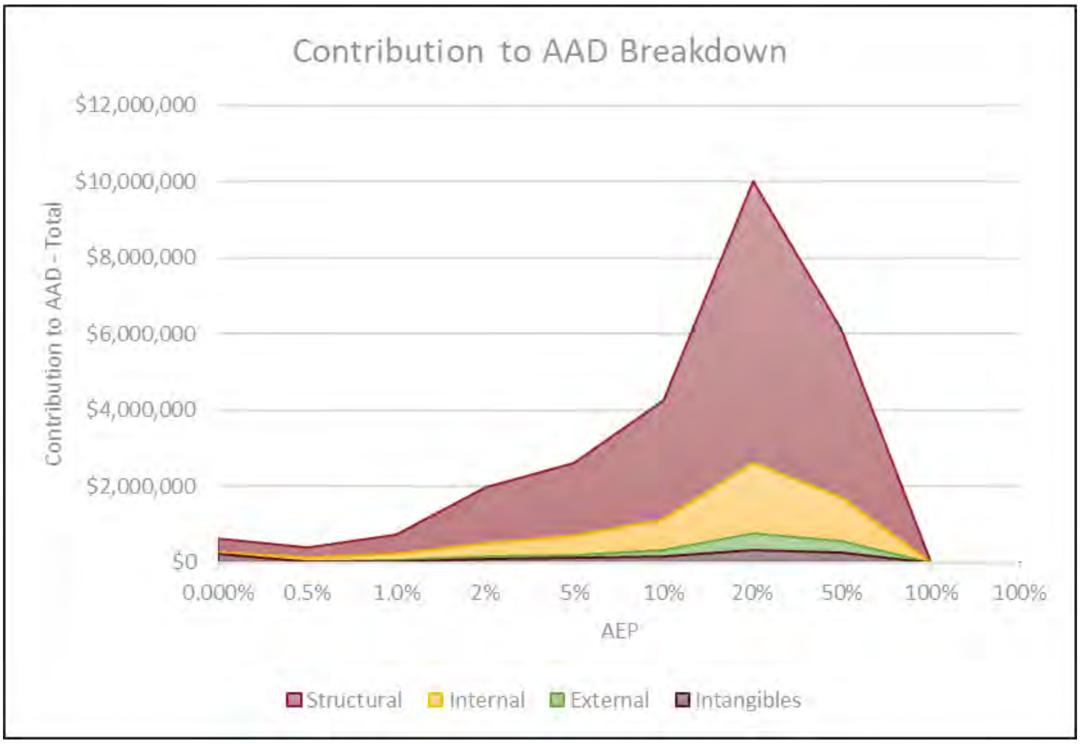

FIGURE 7.8: CONTRIBUTION TO AAD BREAKDOWN

7.6 Flood Planning Area

The flood planning area provides planners a simple tool to identify the areas within a floodplain that may require additional assessment with respect to potential flood impacts. The flood planning area is typically defined as the 1% AEP flood level, plus 0.5 metres freeboard (with the resulting plain extended to intercept with the surrounding landform).

Mapping of the flood planning area is provided in Figure 7.9.

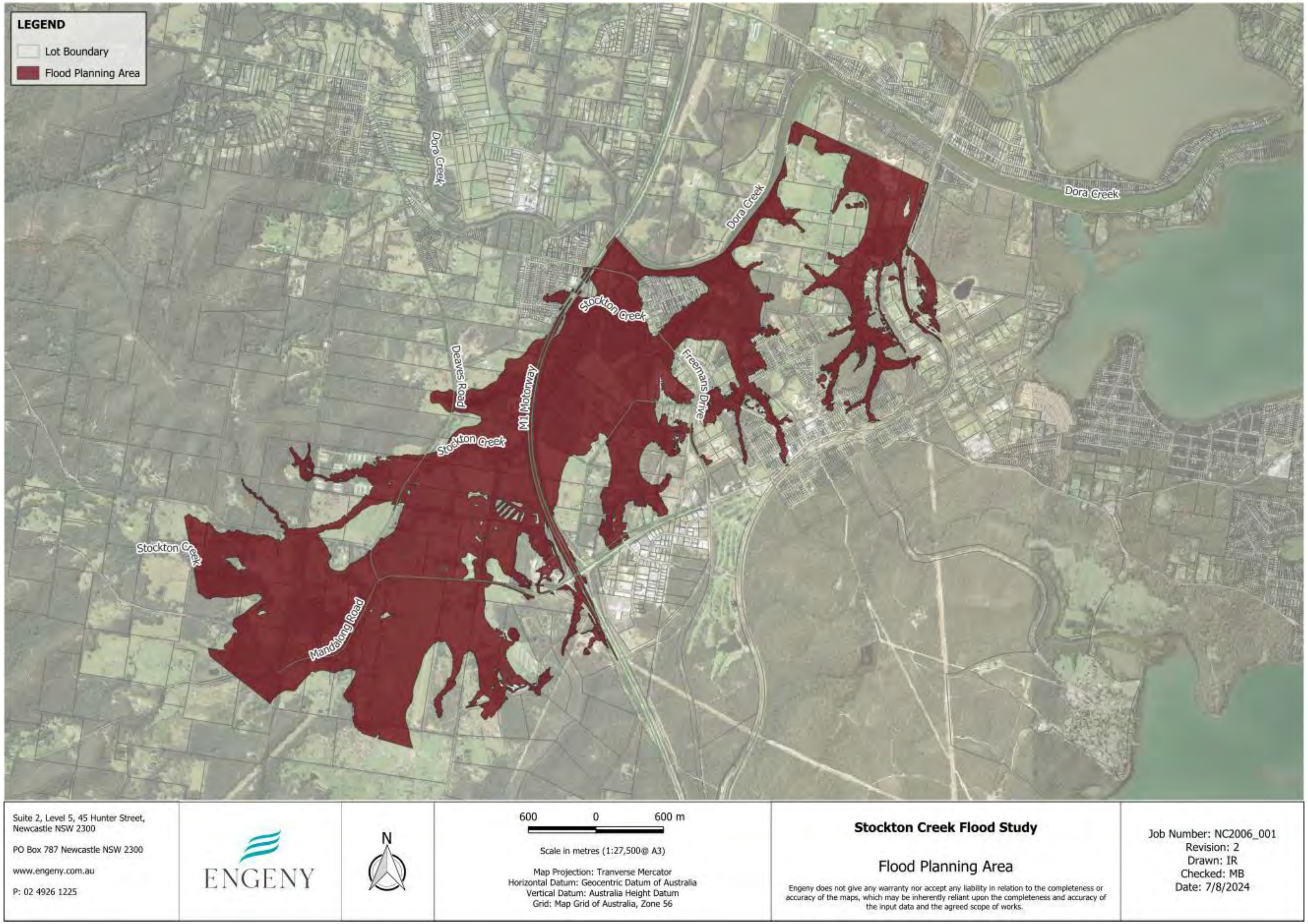

FIGURE 7.9: FLOOD PLANNING AREA

8. NEXT STEPS

The outcomes of this flood study will be used to inform the Morisset Place Strategy, to be developed by Council in order to guide future land use planning for the broader Morisset Area.

9. REFERENCES

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WMA Water, 2015, *Dora Creek Flood Study*

WMA Water, 2015, *Dora Creek Floodplain Risk Management Study and Plan*

10. QUALIFICATIONS

(1) In preparing this document, including all relevant calculation and modelling, Engeny Australia Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

(2) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

(3) Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

(4) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

(5) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

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(8) If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the Report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

(9) This Report does not provide legal advice.

APPENDIX A: QUESTIONAIRE SUMMARY

ENGENY

MEMORANDUM

Project:	NC2006_001	Date:	22 September 2023
To:	**Lake Macquarie City Council**	From:	Engeny
ATT:	Elsa Berger	CC:	
Subject:	Stockton Creek Flooding Questionnaire Summary		

QUESTIONNAIRE SUMMARY

TABLE 1: KEY QUESTIONAIRRE RESPONSES

Response No.	Name of Responder	Address	Flooding on Property	Storm Event	Flood Level	Flood Source
1	Redacted	Redacted	No flooding within property boundary.	None	None	None
2			No flooding within property boundary.			
3			Width of flooding approximately 300m wide resulting in damaged fences and washing away access road. No access to dwelling for 1-2 days.	Every time there is an east coast low e.g. June 2007 April 2015 June 2015 March 2022 July 2022	2m	Runoff from the Watagan mountain further up Mandalong valley.
4			No flooding within property boundary.	None	None	None
5			Yes, minor flooding within a small portion of the property boundary only	18/03/2021.	Didn't measure it exactly, but it was past my ankle.	Land sinking making the water not reach the stormwater drain and the

Response No.	Name of Responder	Address	Flooding on Property	Storm Event	Flood Level	Flood Source
						easiest path for it to go instead was my front yard.
6	Redacted	Redacted	No flooding within property boundary.	We have owned 51 etc Yambo St, Morisset since 1984 and it has never flooded during the eschewing years, and some of these were very wet.	Always dry	na
7			Yes, minor flooding within a small portion of the property boundary only	Pasha Bulker and Others	1 METER	DRAINAGE CHANNEL FROM INDUSTRIAL ESTATE
8			No flooding within property boundary.	Never	Nil	Nil
9			Yes, crop/fencing damage	08/2019 02/2020 03/2021 07/2022	Probabaly 1.5meters, we have had to swim cattle & kyack through the property, over fence lines which were no longer visible	Stockton Creek
10			Flooding within a large portion of the property	July and October 2022	60cm	Overland flow
11			Yes, crop/fencing damage	2007 June 2015 April 2022 July	Variable in paddocks only	Mullards Creek and Stockton Creek only in major events
12			Yes, crop/fencing damage	Every time we have had heavy rain, a few times a year	It floods about 20 feet inside my fence line and I have a temporary back fence as it always catches all the debris	Their is a drain that is between my neighbours and me that gets flooded but it catches all the debris because the water runs so fast it wrecks our side fences as well as my back fence.
13			Bottom paddock floods regularly after heavy raid as Melaleuca Creek now blocked by vegetation and erosion from	Whenever there is a heavy rain event eg multiple time every year. Because of creek blockage paddocks now remain flooded for weeks instead of draining	300mm to 1200mm	Melaleuca Creek blocked. Water draining from the area north of Morisset cannot escape to Dora

Response No.	Name of Responder	Address	Flooding on Property	Storm Event	Flood Level	Flood Source
	Redacted	Redacted	earlier land fill dumped in lagoon.	away in a couple of days as it used to when I first bought the property in 1987. The highest flooding - to the height of the top of the bottom dam wall - occurred on June 9 2017, (height water rose was approx 1200 mm.)		Creek and floods our bottom paddock and neighbours land.
14			Yes, crop/fencing damage	July 2022 and many other dates	about 1 m above the creek bank	Tributary to Morans Creek
15			No flooding within property boundary.			
16			No flooding within property boundary.			
17			Yes, significant flooding within grounds and garage but not above floor level.	Every year we have been here since 2015. Usually around June	1 M + in some places	Creek overflow from Tobins Creek. Stockton Creek and Morans Creek.
18			No flooding within property boundary.		N/A	N/A
19			Build up of rain around drains	I am the Team Leader and this was before more time.	Only ever been a build up of rain fall around the drains down near the bottom of the front gates when its been particularly wet but otherwise all good. I would imagine this has come from flooding improvements for Dora Creek that the majority of the town sits on the creek wall and does flood.	AS above.
20	Redacted		Stingaree Point Dr was also closed due to flooding	I have lived in several streets in Dora Creek for last 25 years. Each of there streets have been impacted by flooding. First one was 2007 Oasha Bulka storm. My house in Dora St was impacted and	Current house calf deep in yard on road it was knee deep this was heavy rains in 2022 July I think	Drainage in yard and erosion. Lake was breaking banks into back yard. Front yard run off from other properties and no Drainage at all. Road creek broke it banks and flooded road

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Response No.	Name of Responder	Address	Flooding on Property	Storm Event	Flood Level	Flood Source
				my partner house in Kalang Rd was impacted badly as well		
21	Redacted	Redacted	Yes, significant flooding within grounds and garage but not above floor level.	I have lived in several streets in Dora Creek over 25 years. Each one of those streets I have experienced flooding. Either in my house or road and surrounds	2007 pasha bulka storm. I lived in Dora St. Flooded whole yard, had to be evacuated. Streets were closed. My partner lived in Kalang Rd. House suffered significant damage. This was my first experience of flooding in this area. Since then, each property I have lived at has been affected one way or another	Due to erosion, Lake was smashing into back yard and flooded. Front yard was flooded due to neighbouring properties run off and no street drainage, so all of the road water comes into my yard
22			Yes, crop/fencing damage	Oct 2020 March 2021 July 2022	Up to 1 metre over access bridge	Morans creek
23			No flooding within property boundary.			flooding on Mandalong road is due to the water coming from the mountains.
24			Yes, significant flooding within grounds and garage but not above floor level.	All storms with enough rainfall in the localized area to cause out of streambank flooding.	Hazardous flood depth	Moran's Creek and Drainage Line off Mandalong Road Catchment (Watagan Mountains).
25			major flooding on parts of property major fooding on access to property		one metre depth fast flowing	gullies and creek
26			No flooding within property boundary.			
27			Enter to property washed away	All	Metres	All of the above
28			Yes, minor flooding within a small portion of the property boundary only	July 2020, Feb 2022 & more (exact dates I can't remember by heart)	A reasonable portion of the property was flooded (approx 70%), the creek that runs through the property was over flowing, our two	

Response No.	Name of Responder	Address	Flooding on Property	Storm Event	Flood Level	Flood Source
					dams were over flowing causing more flooding through the property.	
29	Redacted	edacted	Yes, significant flooding within grounds and garage but not above floor level.	Multiple - have been cut off a number of times in last few years - heavy rain covers driveway and road - Mandalong road frequently cut by floodwater - one in feb 2020	waist height in some paddocks, over knee height across driveway	Rain run off from surrounding mountains into Mandalong valley. Creeks and streams fill and spread very quickly across valley floor in high rain fall events
30			Yes, significant flooding within grounds and garage but not above floor level.	All Storm events since 1983	About 1 meter	Morgan's creek overflows
31			Yes, crop/fencing damage	Feb 2020, Mar 2021, May 2014, Mar 2015	1metre in flooded areas which then spread across low paddocks	Creek and overland flow
32			Yes, crop/fencing damage	1989 worst in memory date not recorded 2007June 2015 April	Entry blocked at gate (refer photos) Internal road leading to house 1.2m under water	overland flow
33			No flooding within property boundary.	Nil	Nil	Nil
Email/ Letter Responses - Summary						
34	Redacted	Redacted	Been living in Mandalong since 2001 and have experienced many flooding events.	June 2007 event, (Pasha Bulka etc)	I spent 24 hrs as the driver of the Mandalong RFS truck. During this time at about 10 pm we were parked on Mandalong Rd about 50m from Deaves Rd. I remember that the headlights on the truck were under the water level as when traveling the passenger held a spot light out the window so that I could see where I was driving. This means that the water level was greater than 1m. You should be able to estimate the water level contours in the proposed industrial area from this observation	
35			I moved to Mandalong in 1955 & have lived and owned several lots of land in Mandalong sense that time, including land adjacent to Morans Creek on Mandalong Rd for most of that time. I have a very good knowledge of the flood history in the Morans Creek & Stockton Creek areas. There was several minor flood events in the early years, I have never seen Morans Creek break its banks.			

Response No.	Name of Responder	Address	Flooding on Property	Storm Event	Flood Level	Flood Source
			Following the raising of Mandalong Rd, the redirection of the water flows south of Mandalong Rd by blocking off 5 small culverts on Mandalong Rd and channeling the water slow into Stockton Creek and the mitigation work further down stream as part of the construction of the M1 Motorway also the mitigation work carried out as part of the Consent Conditions for the Mandalong Mine, has all significantly reduced the likelihood in my opinion of any major flooding in the vicinity of Morans Creek in the future. The biggest flood event in the area1989 & in June 2017 when the Pasa Bulker was beached in Newcastle & when Lake Macquarie broke its banks due to the super king tide a greater than a 1/100 year flood event, didn't cause Morans Creek to overflow, is certainly a fair indication that it is very unlikely that there will be a major flood event in the Morans Creek area in the future. There is some minor flooding on the low-lying areas north of Mandalong Rd near the Stockton Creek bridge on the corner of Deaves Rd & Mandalong Rd & further down stream in major flood events.			
36	Redacted	Redacted	I have lived and owned several lots of land in Mandalong over the past 68 years including living on land adjacent to Morans Creek on Mandalong Rd for most of that time. I have a very good knowledge of the flood history in the Morans Creek & Stockton Creek areas. Whilst in the early years there were several minor flood events, I have never seen Morans Creek break its banks. Following the raising of Mandalong Rd, the redirection of the water flows south of Mandalong Rd by blocking off 5 small culverts on Mandalong Rd and channelling the water slow into Stockton Creek and the mitigation work further down stream as part of the construction of the M1 Motorway also the mitigation work carried out as part of the Consent Conditions for the Mandalong Mine, has all significantly reduced the likelihood in my opinion of any major flooding in the vicinity of Moran's Creek in the future. There is some minor flooding near the Stockton Creek Bridge on Deaves Rd in major flood events.			

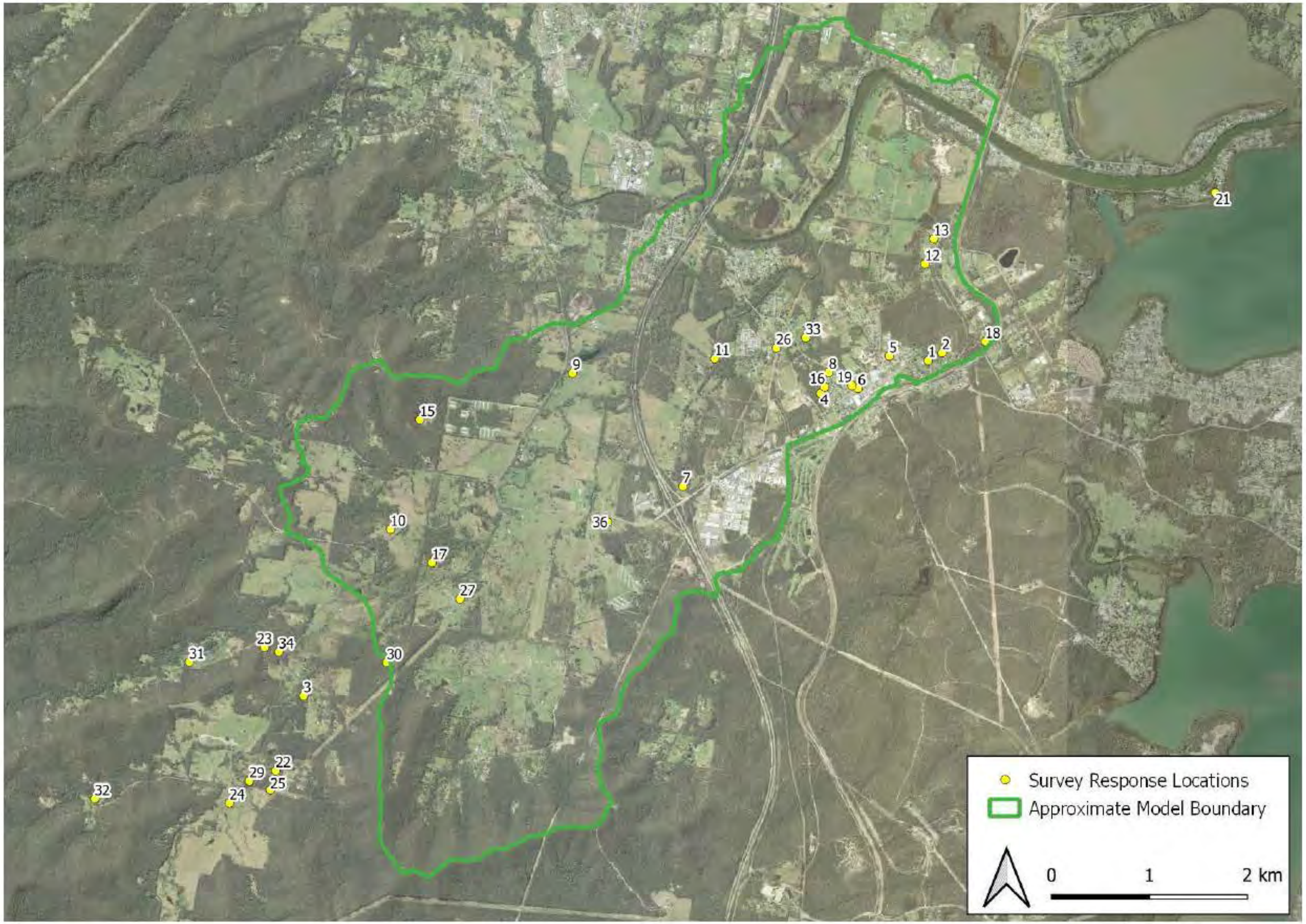

Figure 1: Questionnaire Response Locations (Label numbers correspond to response number in Table 1 above)

FLOODING PHOTOS

TABLE 2: PHOTO EVIDENCE

Address	Storm Event	Photos
Redacted	3/3/2023	     

Address	Storm Event	Photos
Redacted	NA	   

Address	Storm Event	Photos
Redacted	5/7/2023	 
Redacted	1989	

Address	Storm Event	Photos
		 Water spanning the top of Mandalong Valley. Corner of Little Valley & Mandalong Rds. Chapmans Road is in the background – 1989 Flood   
Redacted	August 2019	  

Address	Storm Event	Photos
		
	February 2020	     

Address	Storm Event	Photos	
	March 2021		

Address	Storm Event	Photos
	August 2022	   

Address	Storm Event	Photos
Redacted	09/02/2020	     
	19/02/2020	 

Address	Storm Event	Photos
	19/03/2021	   
Redacted	NA	 

Address	Storm Event	Photos
Redacted	NA	
Redacted	NA	

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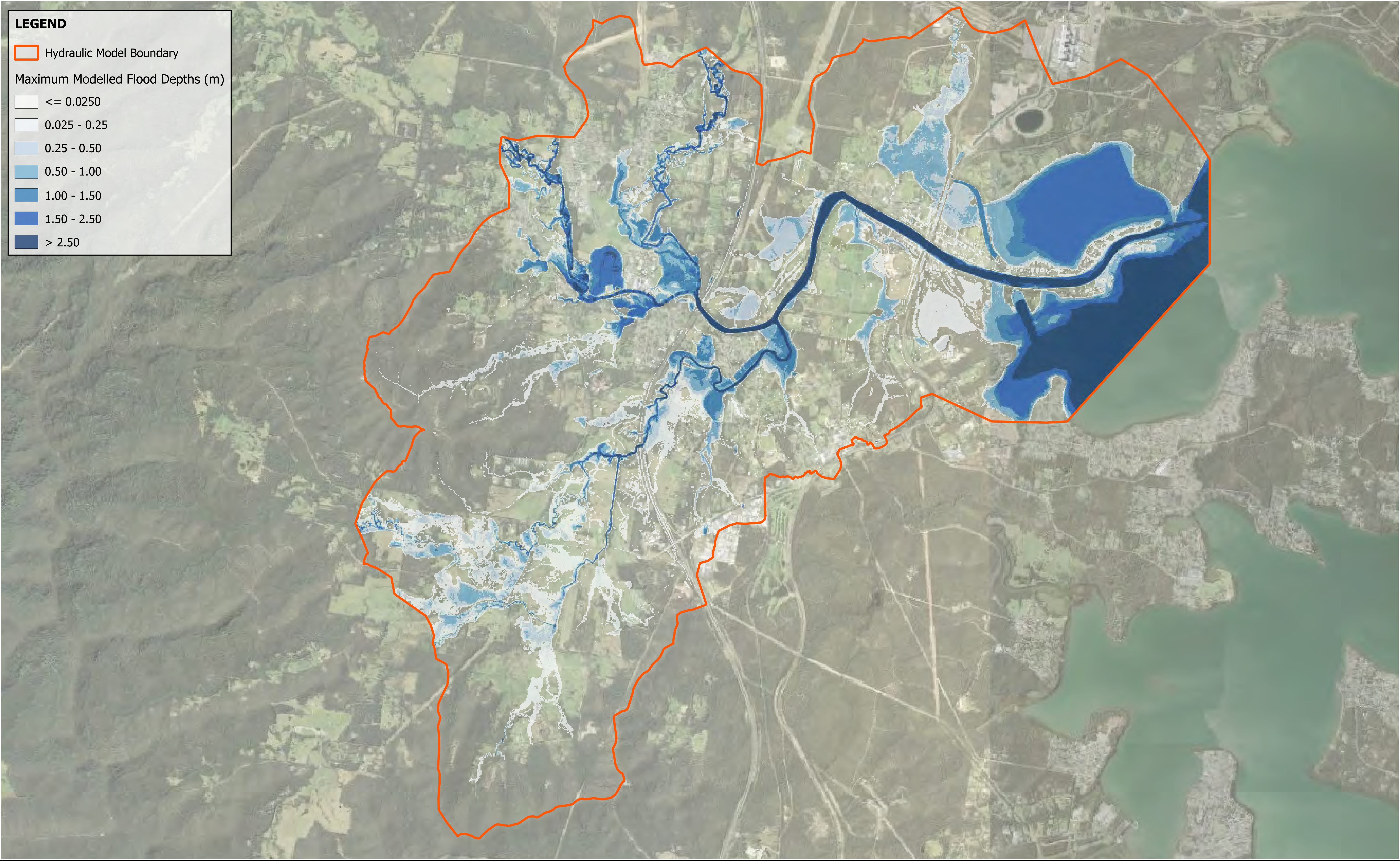
APPENDIX B: FLOOD MAPPING



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Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.1: 50% AEP (2 Year ARI)

Maximum Flood Depths

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024

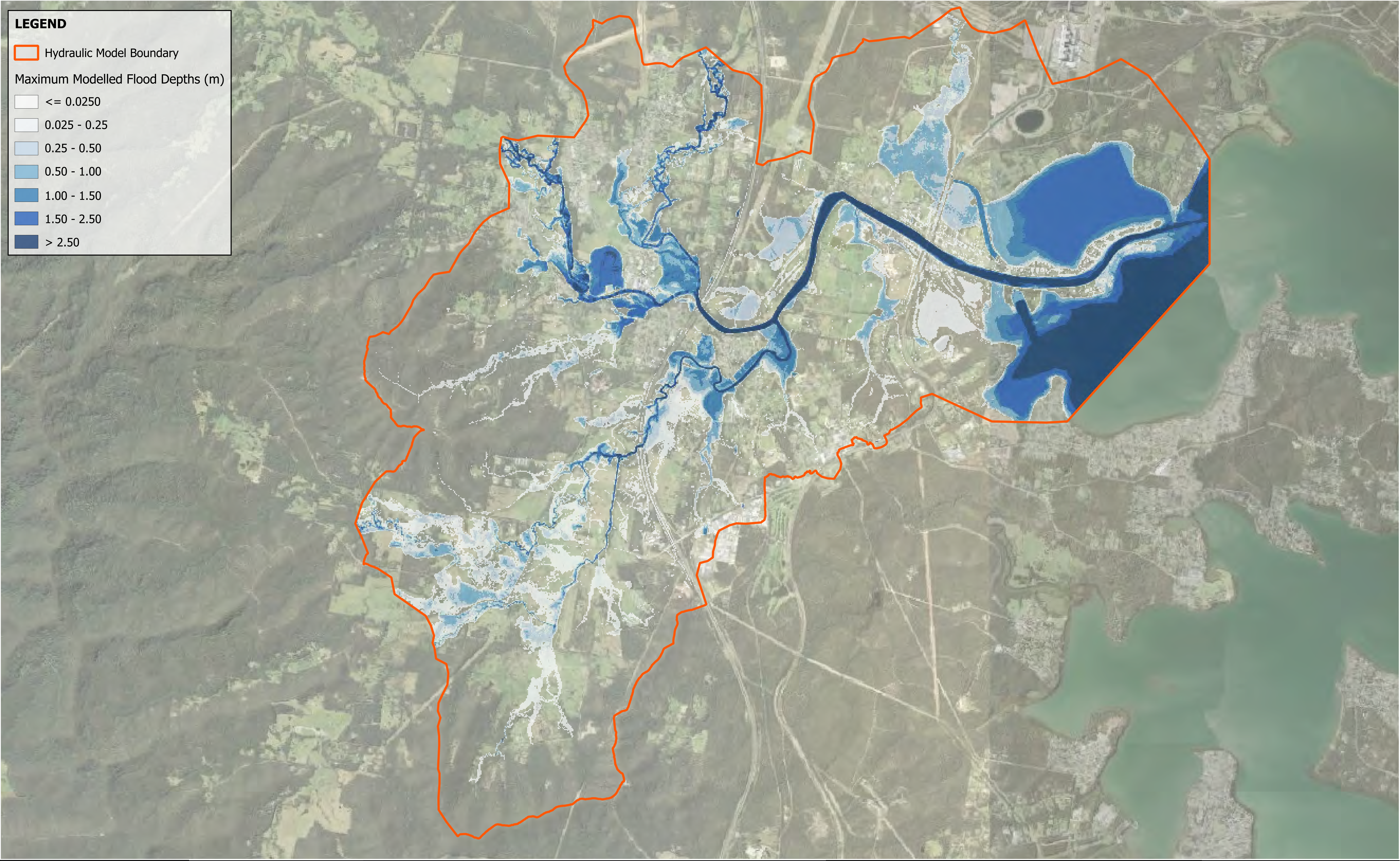

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Figure B.1: 50% AEP (2 Year ARI)

Maximum Flood Depths

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024

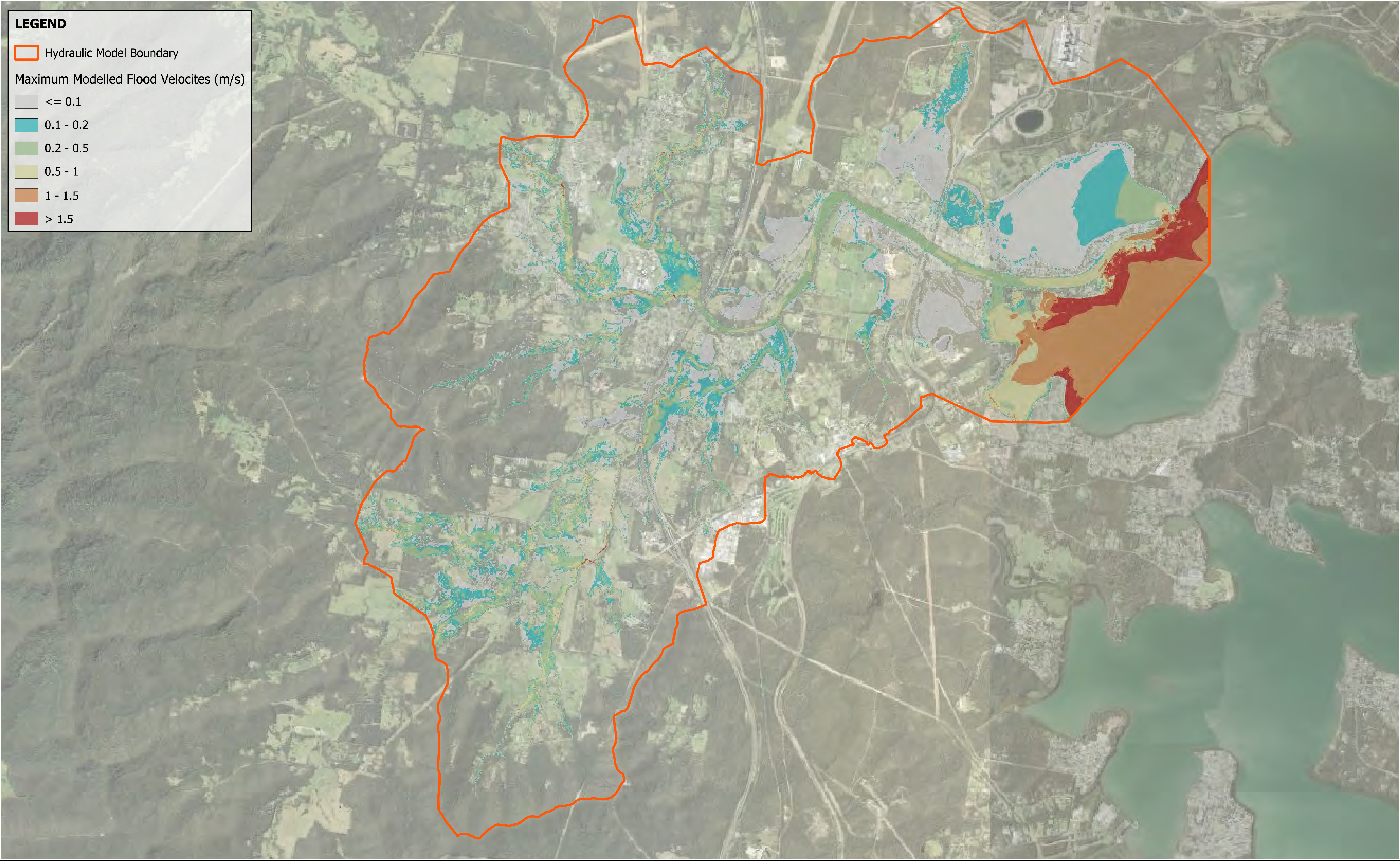

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Figure B.2: 50% AEP (2 Year ARI)

Maximum Flood Velocities

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024

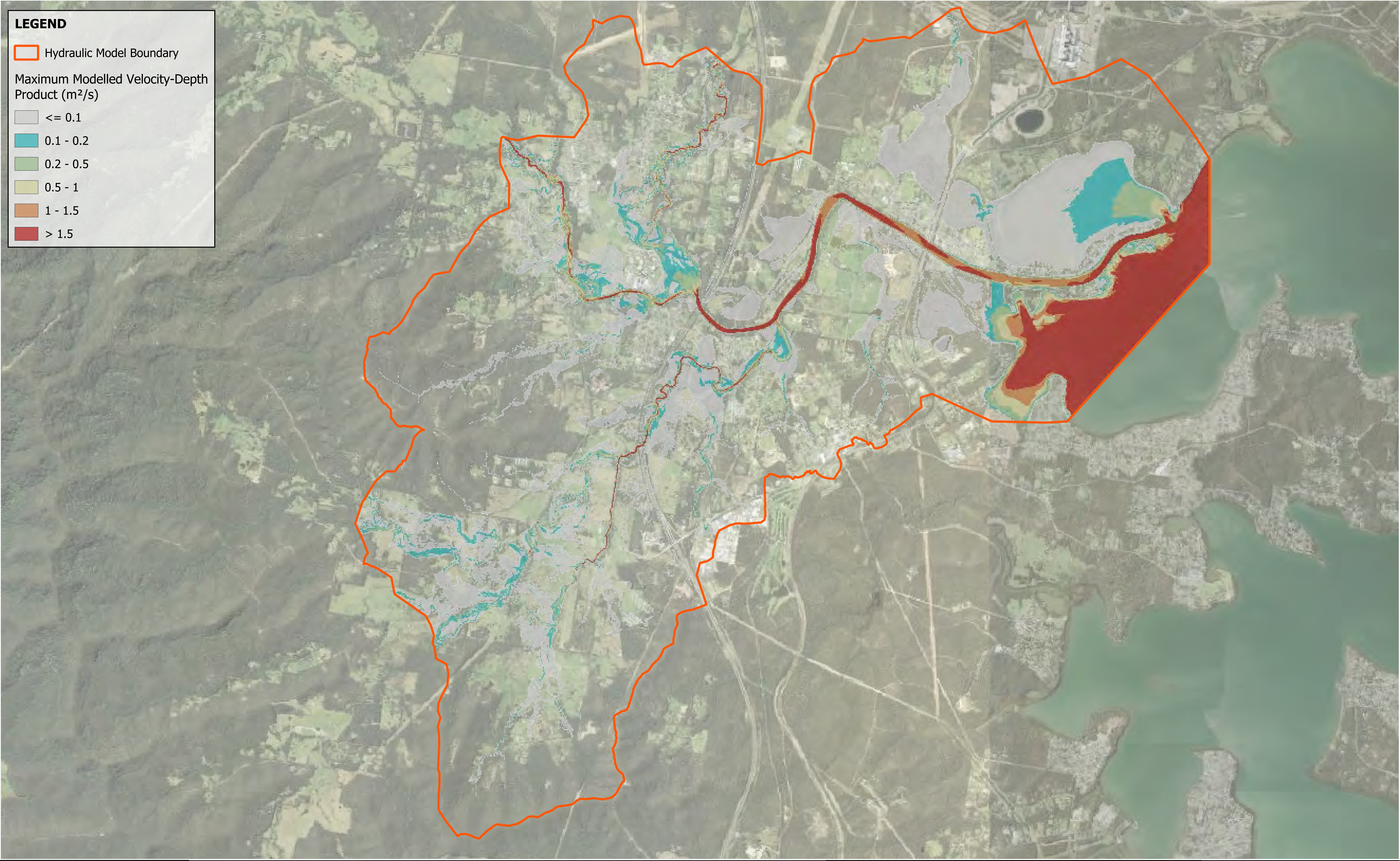

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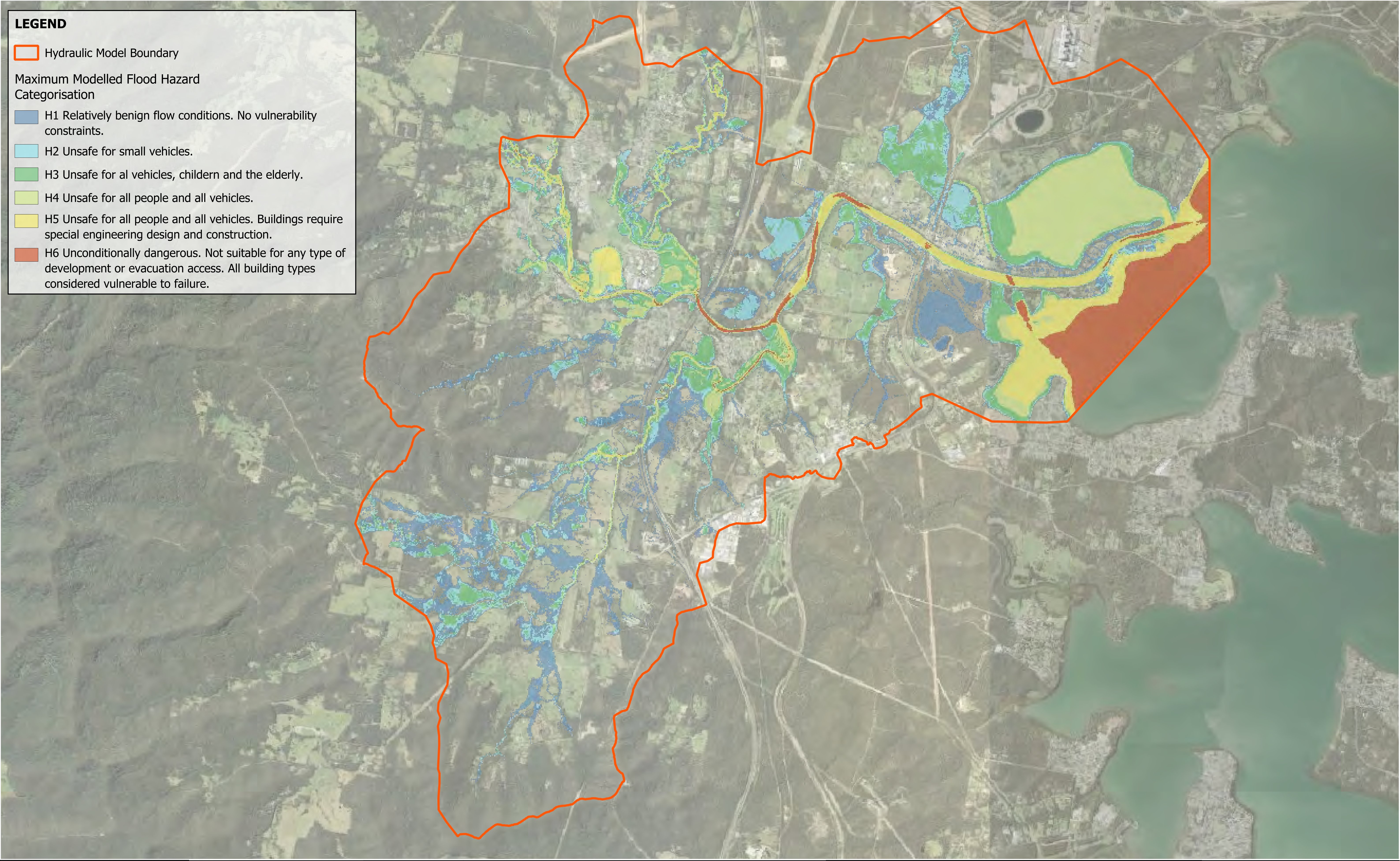
Figure B.3: 50% AEP (2 Year ARI)

Maximum Flood Velocity- Depth Product

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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Map Projection: Tranverse Mercator
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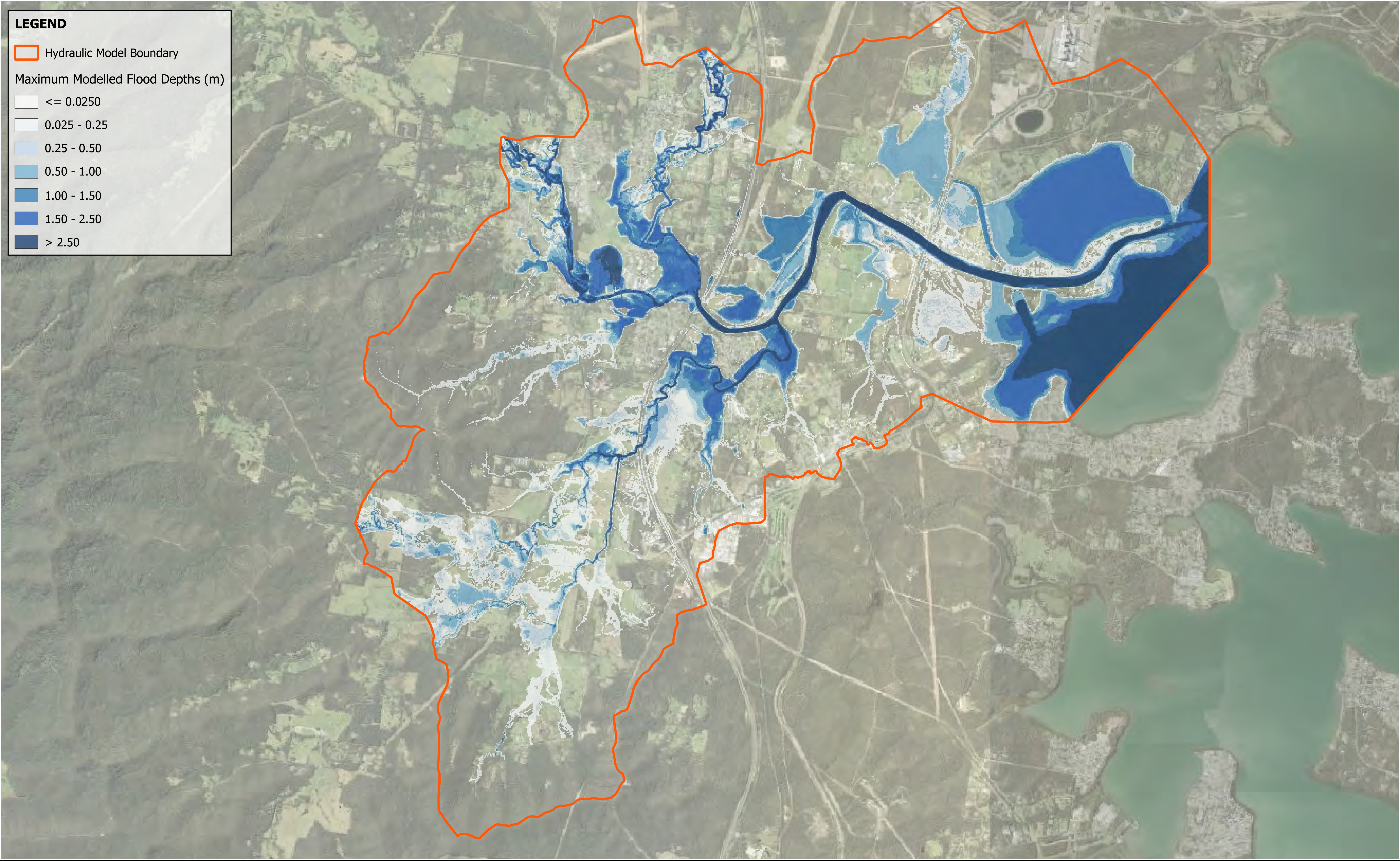
Figure B.4: 50% AEP (2 Year ARI)

Maximum Flood Hazard Categorisation

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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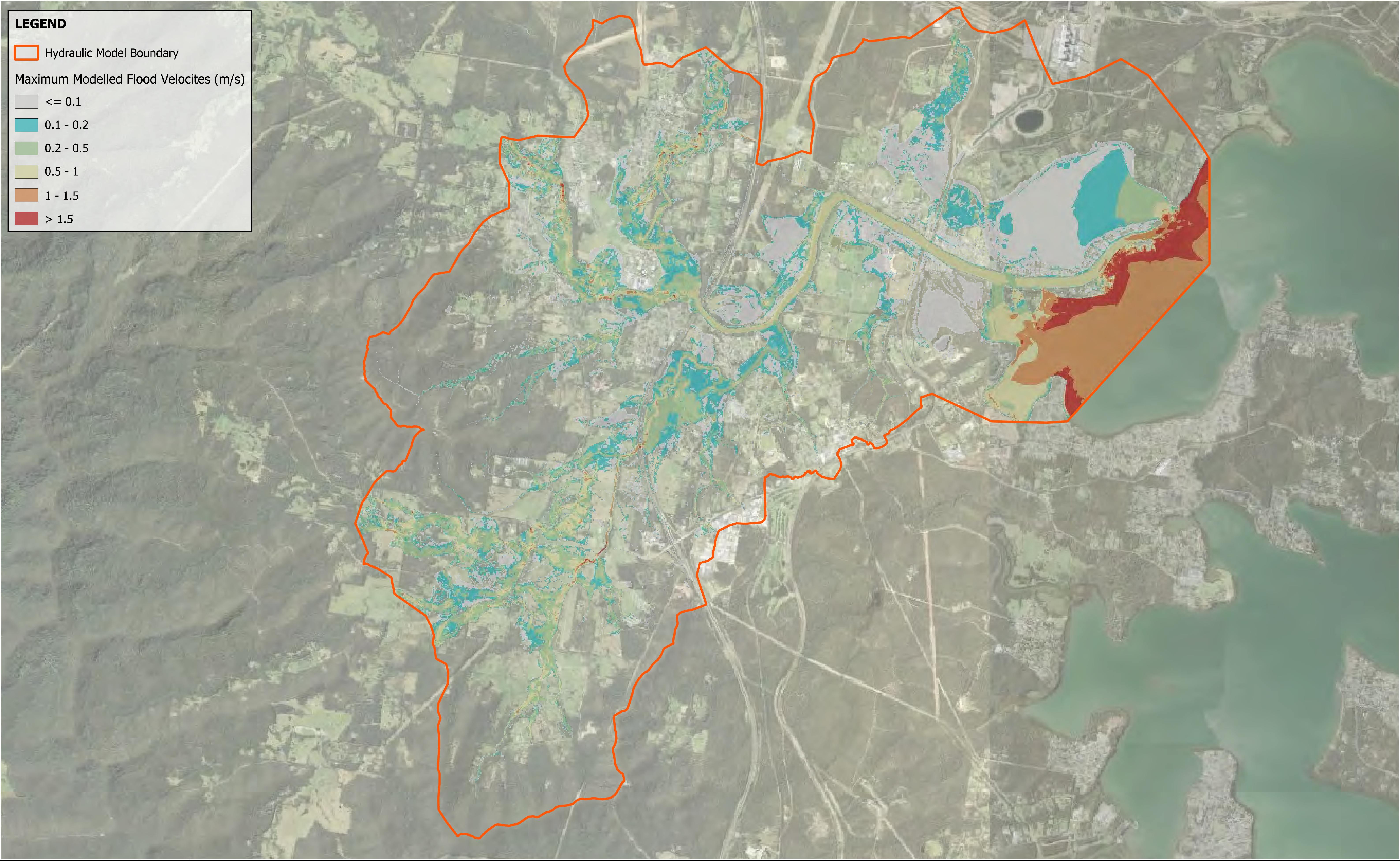
Grid: Map Grid of Australia, Zone 56

Figure B.5: 20% AEP (5 Year ARI)

Maximum Flood Depths

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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Grid: Map Grid of Australia, Zone 56

Figure B.6: 20% AEP (5 Year ARI)

Maximum Flood Velocities

Job Number: NC2006_001
Revision: 0
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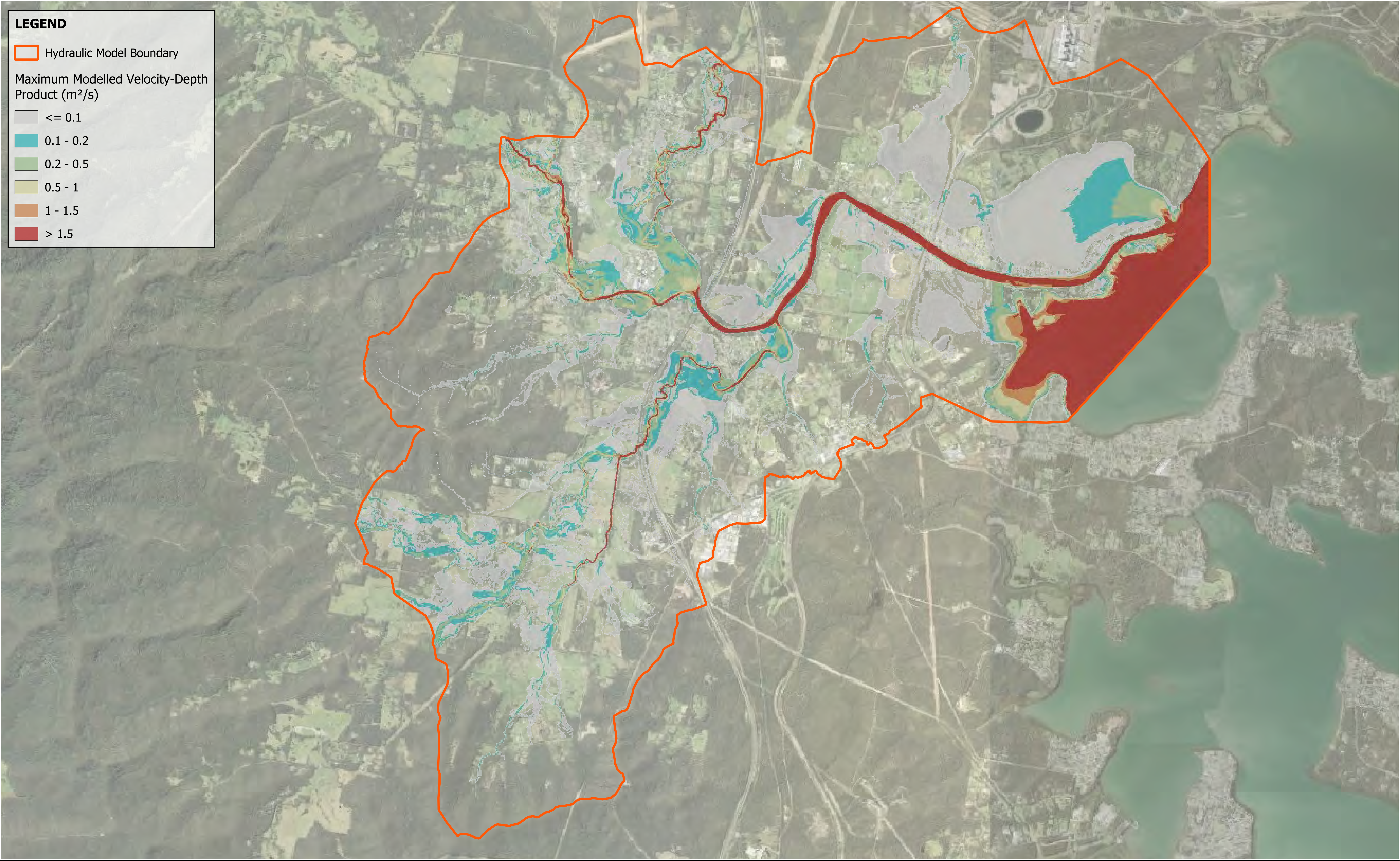
Date: 31/7/2024



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Map Projection: Tranverse Mercator
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Figure B.7: 20% AEP (5 Year ARI)

Maximum Flood Velocity- Depth Product

Job Number: NC2006_001
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Drawn: IR
Checked: MB
Date: 31/7/2024

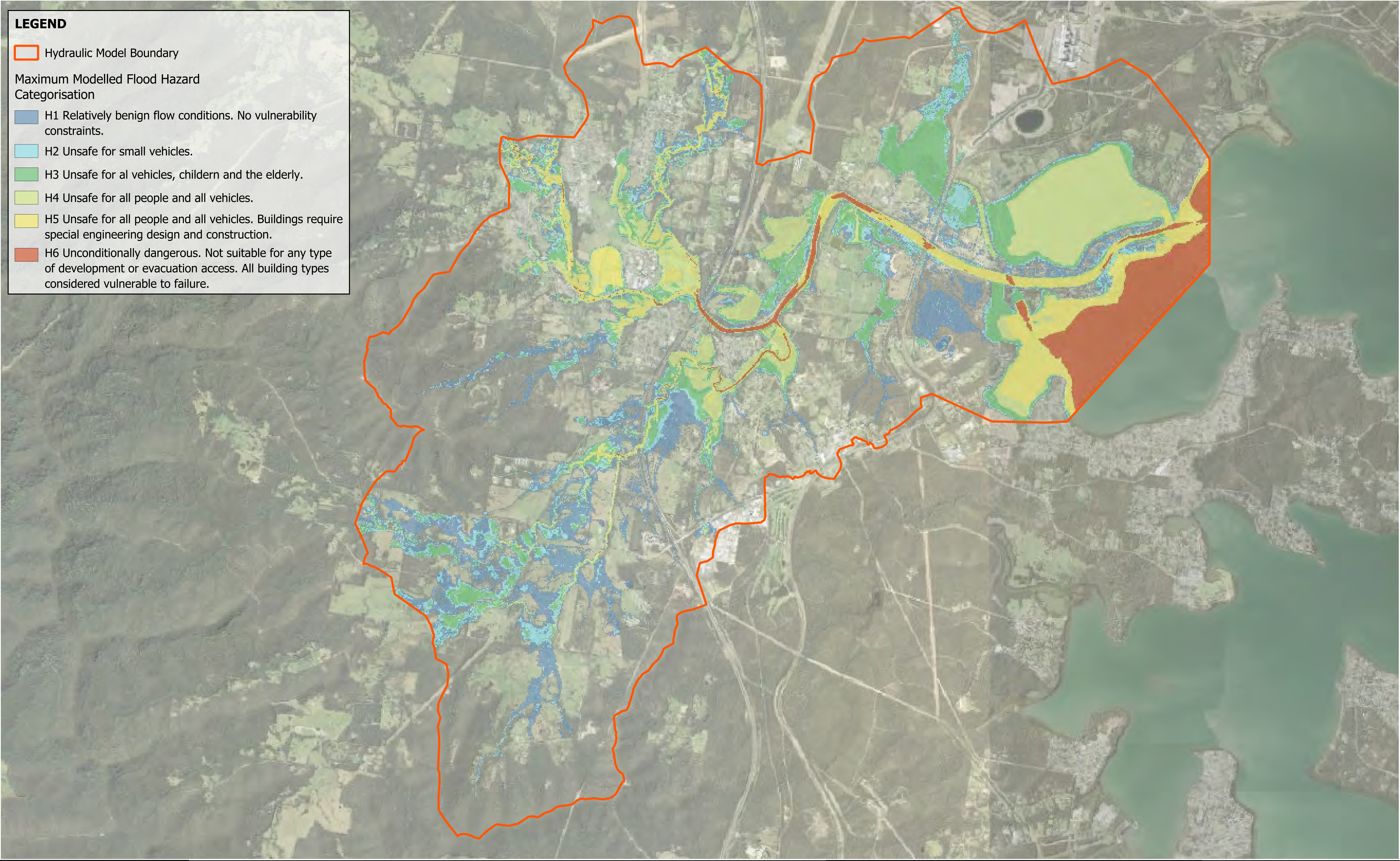

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Figure B.8: 20% AEP (5 Year ARI)

Maximum Flood Hazard Categorisation

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Revision: 0
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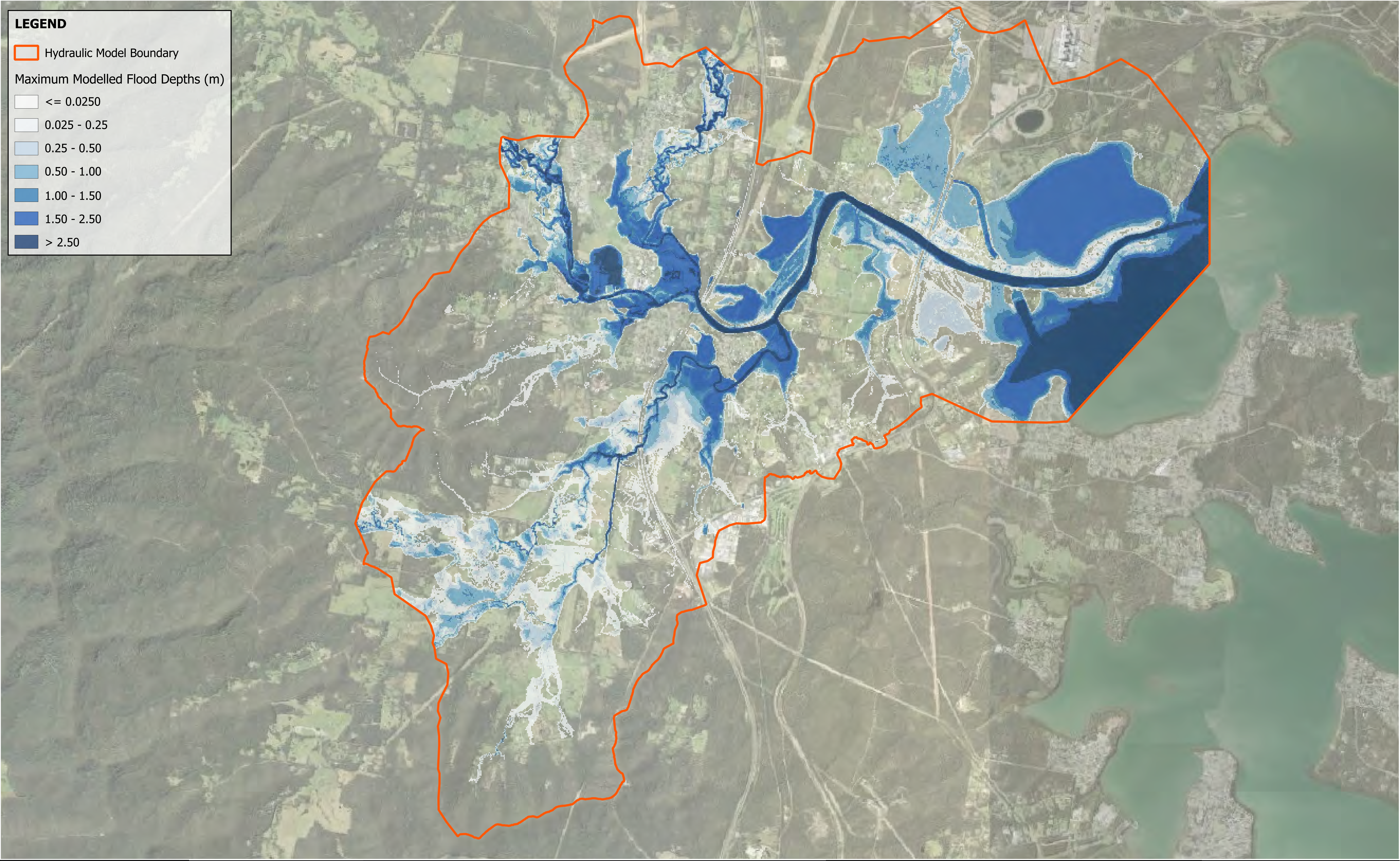
Date: 31/7/2024



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Vertical Datum: Australia Height Datum
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Figure B.9: 10% AEP (10 Year ARI)

Maximum Flood Depths

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024

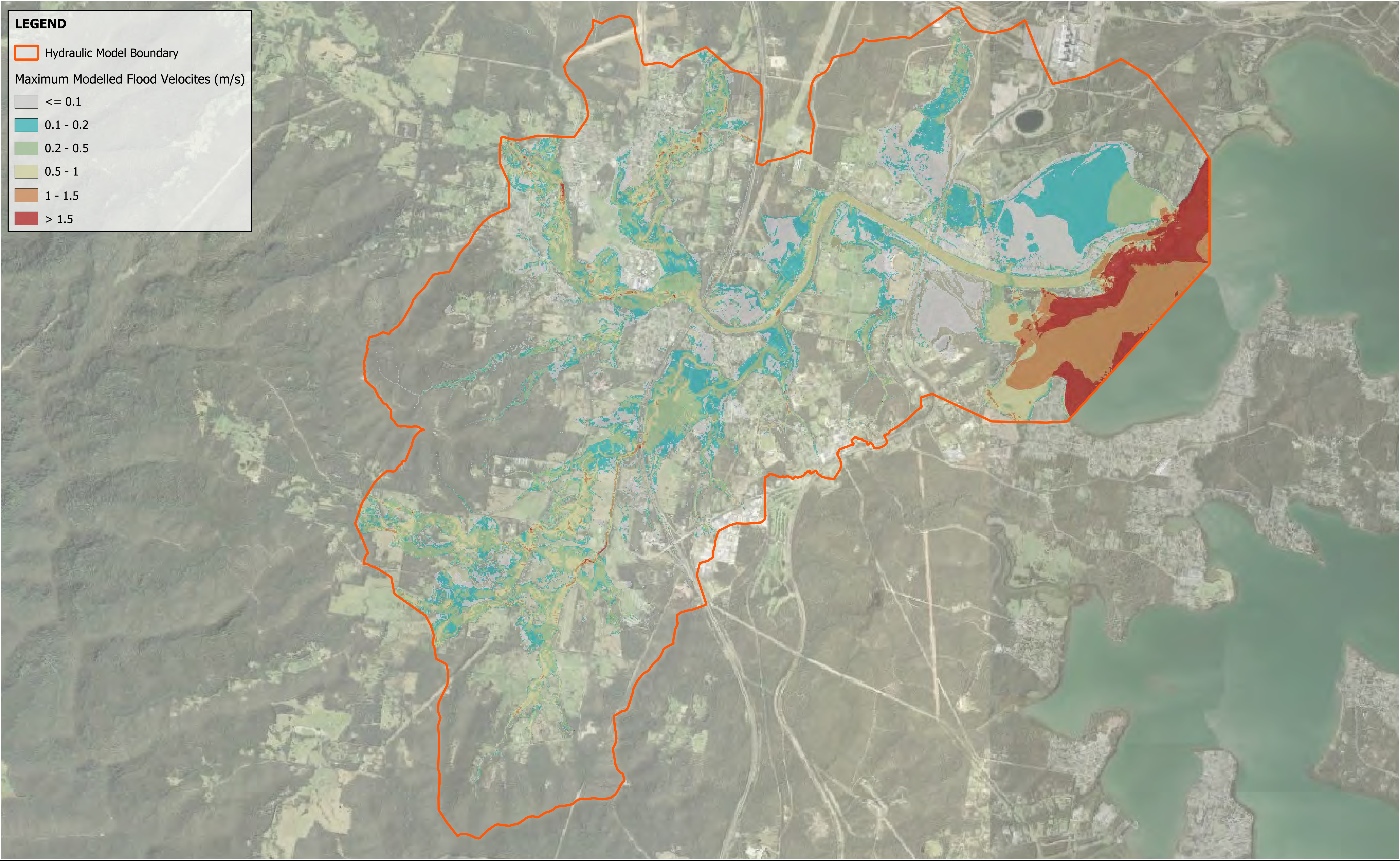

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Figure B.10: 10% AEP (10 Year ARI)

Maximum Flood Velocities

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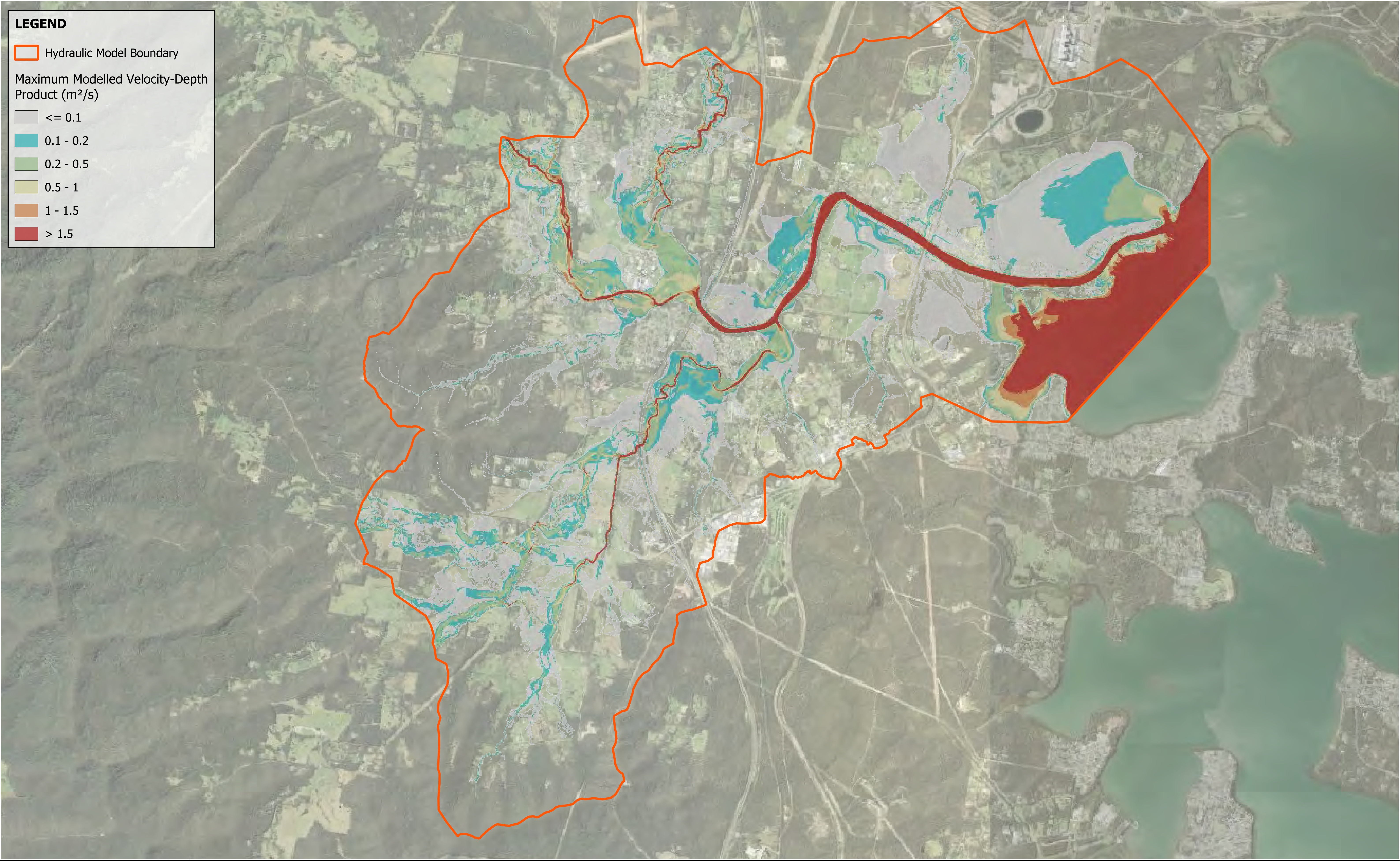
Date: 31/7/2024



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Horizontal Datum: Geocentric Datum of Australia
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Figure B.11: 10% AEP (10 Year ARI)

Maximum Flood Velocity- Depth Product

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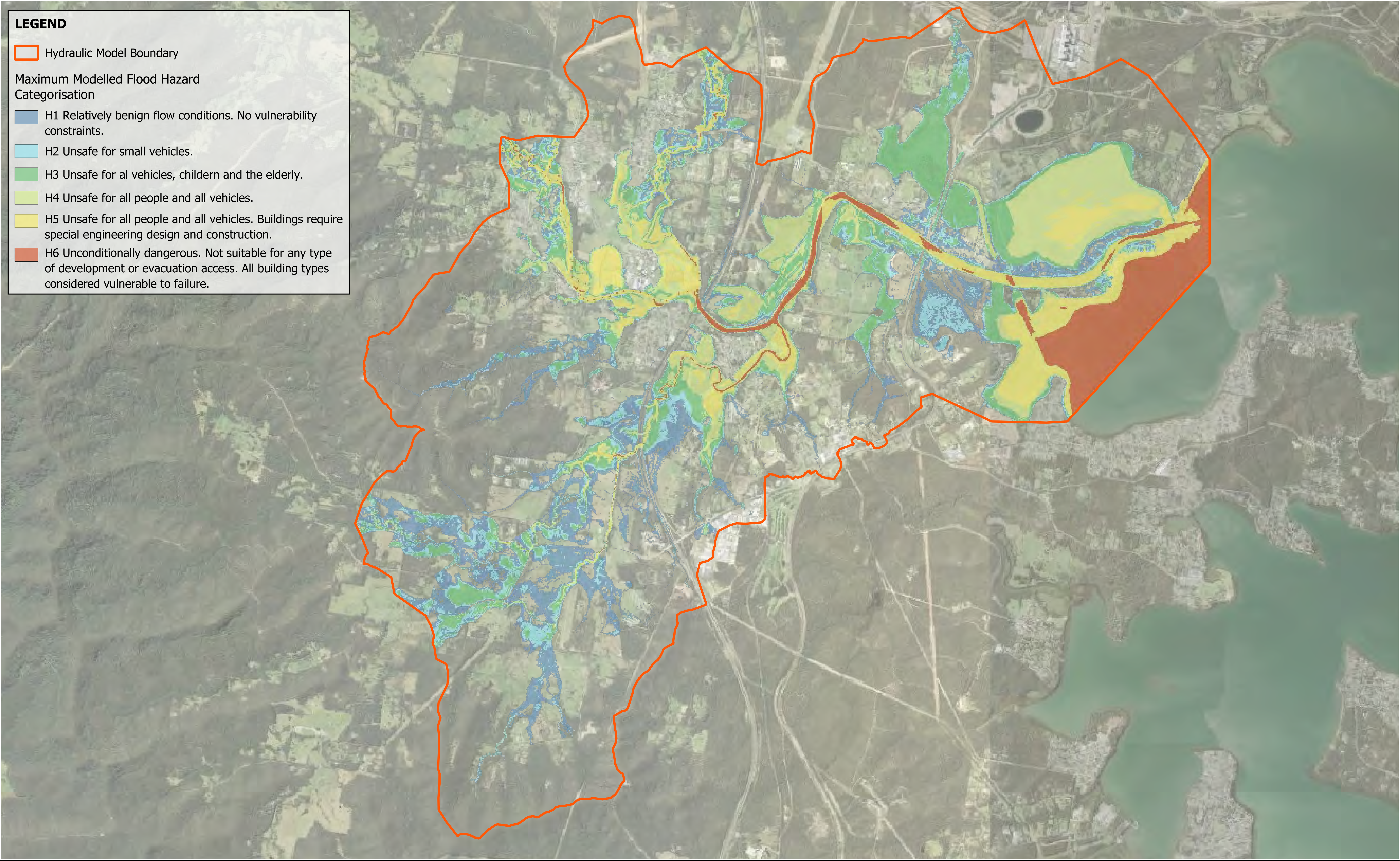
Date: 31/7/2024



Suite 2, Level 5, 45 Hunter Street, Newcastle NSW 2300 PO Box 787 Newcastle NSW 2300 www.engeny.com.au P: 02 4926 1225	ENGENY	N	1,000 0 1,000 m Scale in metres (1:42,500@ A3) Map Projection: Tranverse Mercator Horizontal Datum: Geocentric Datum of Australia Vertical Datum: Australia Height Datum Grid: Map Grid of Australia, Zone 56	**Figure B.12: 10% AEP (10 Year ARI)** Maximum Flood Hazard Categorisation Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the maps, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works.	Job Number: NC2006_001 Revision: 0 Drawn: IR Checked: MB Date: 31/7/2024

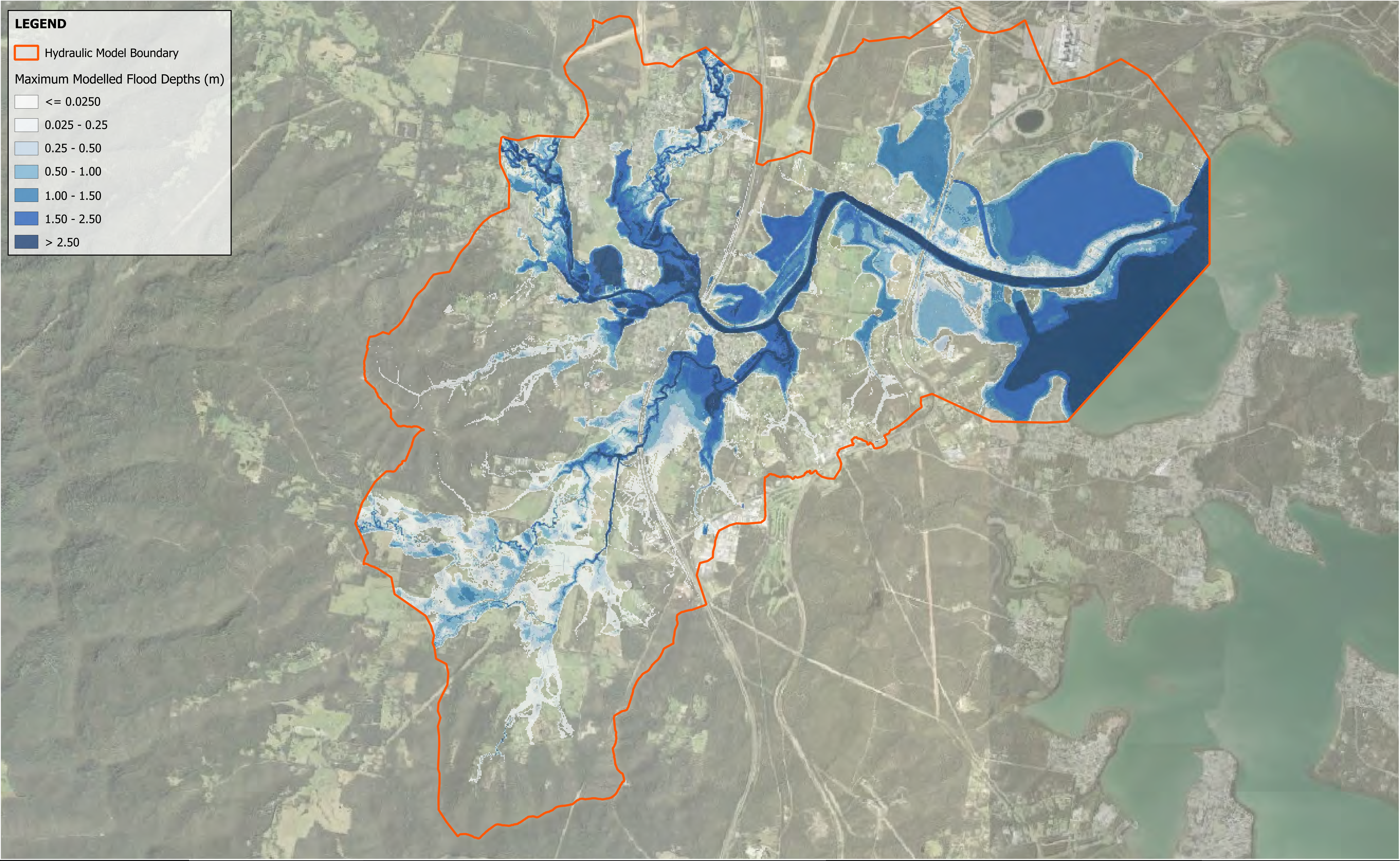


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Figure B.13: 5% AEP (20 Year ARI)

Maximum Flood Depths

Job Number: NC2006_001
Revision: 0
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Date: 31/7/2024

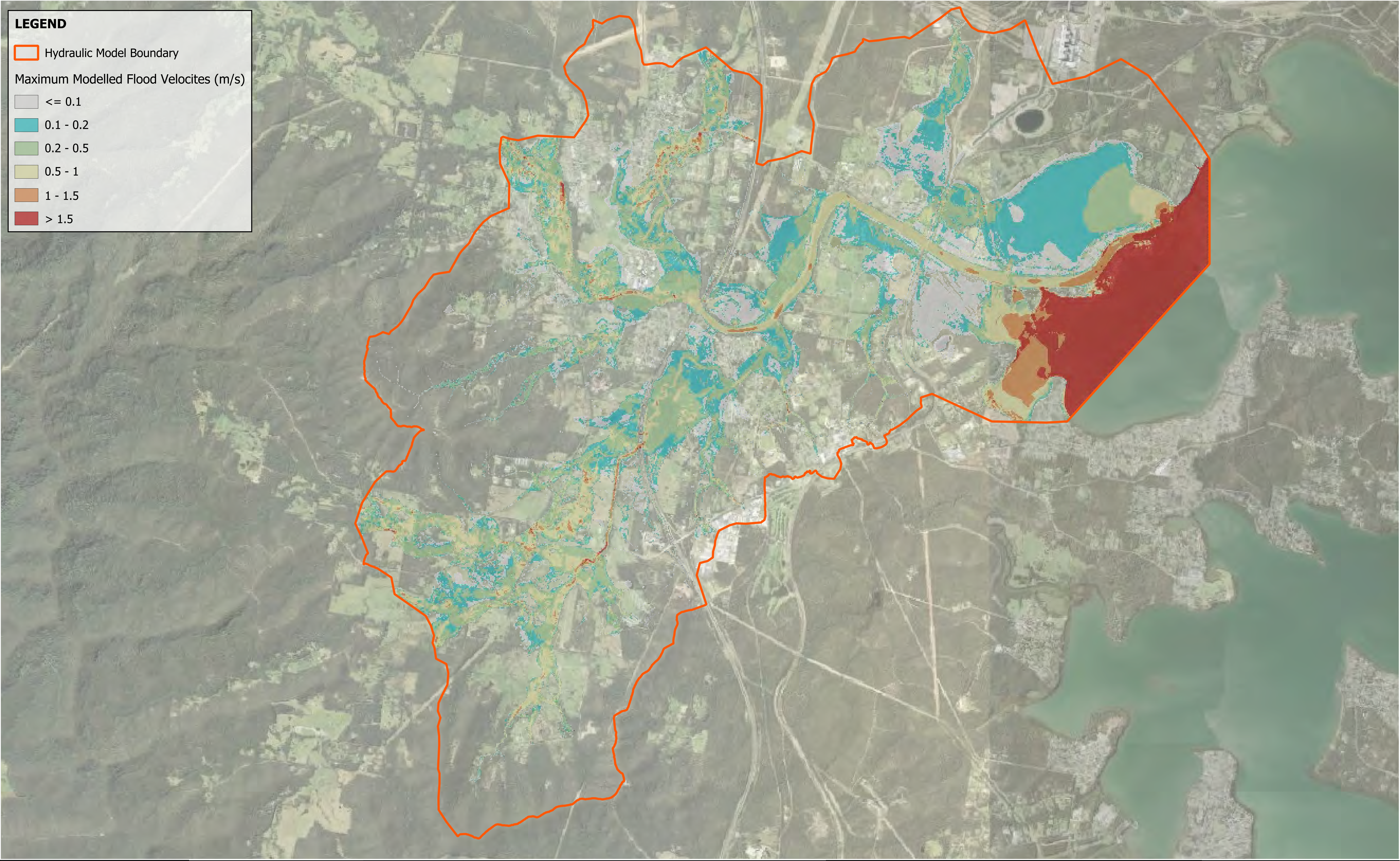

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Figure B.14: 5% AEP (20 Year ARI)

Maximum Flood Velocities

Job Number: NC2006_001
Revision: 0
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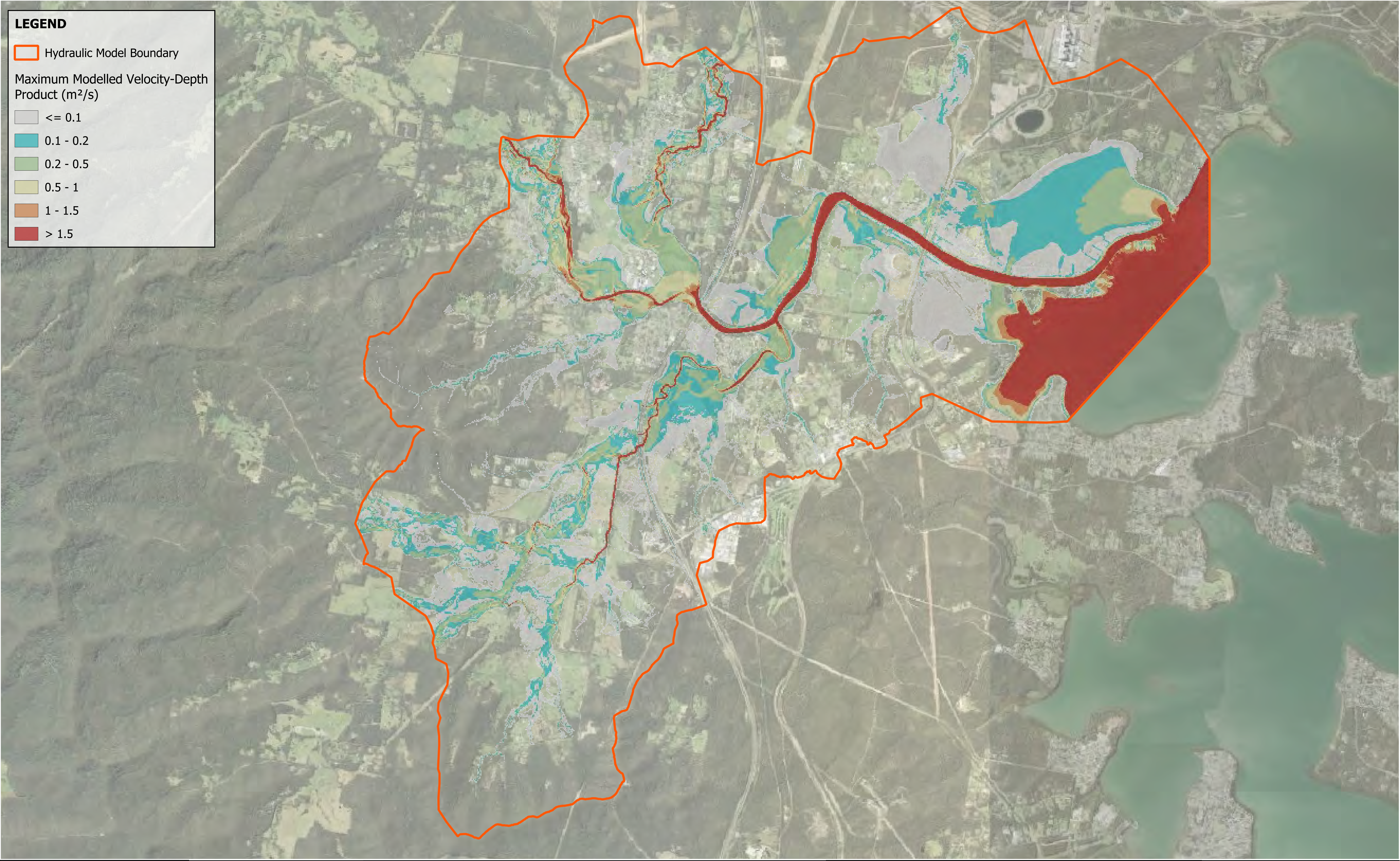
Checked: MB
Date: 31/7/2024



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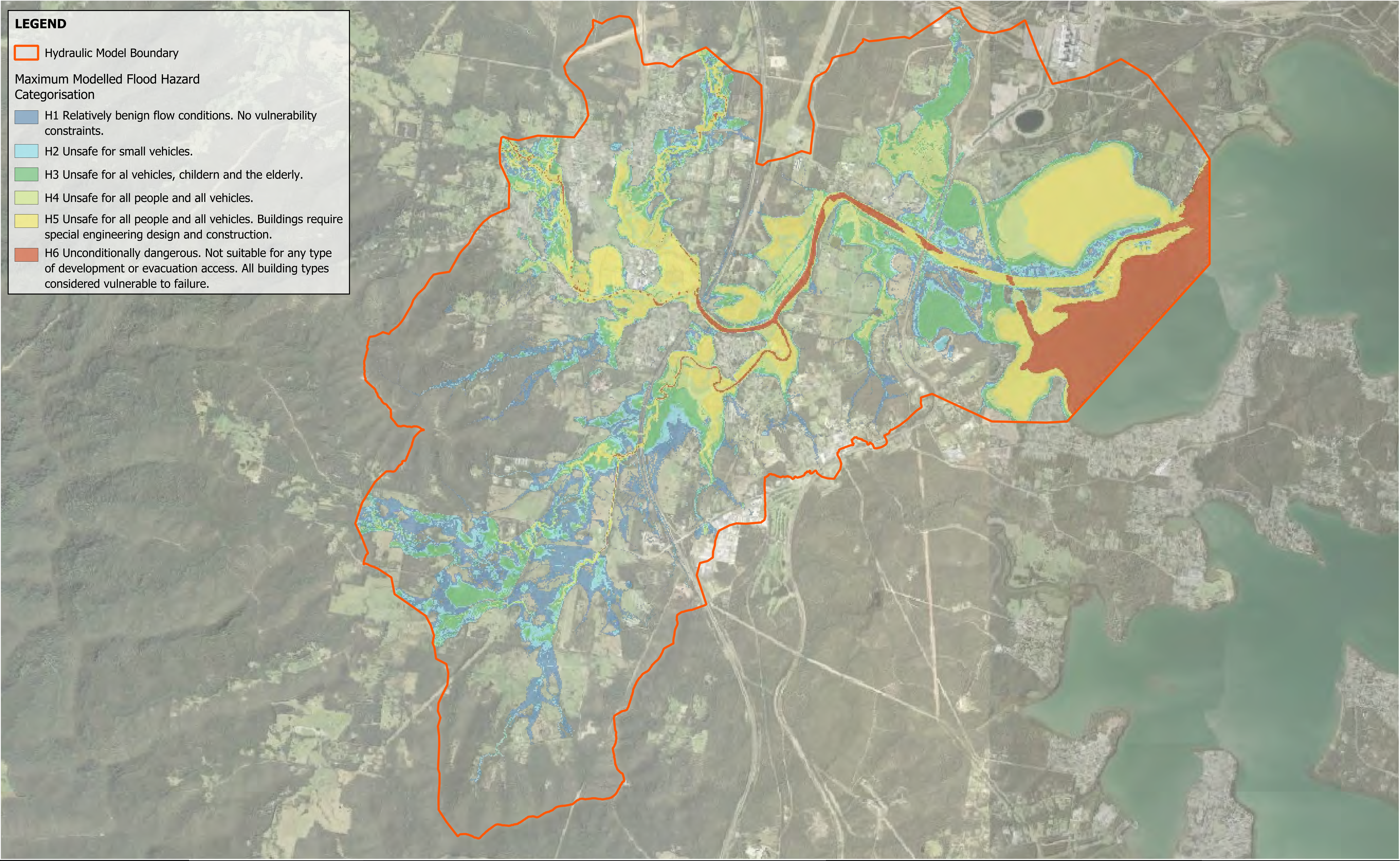
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.15: 5% AEP (20 Year ARI)

Maximum Flood Velocity- Depth Product

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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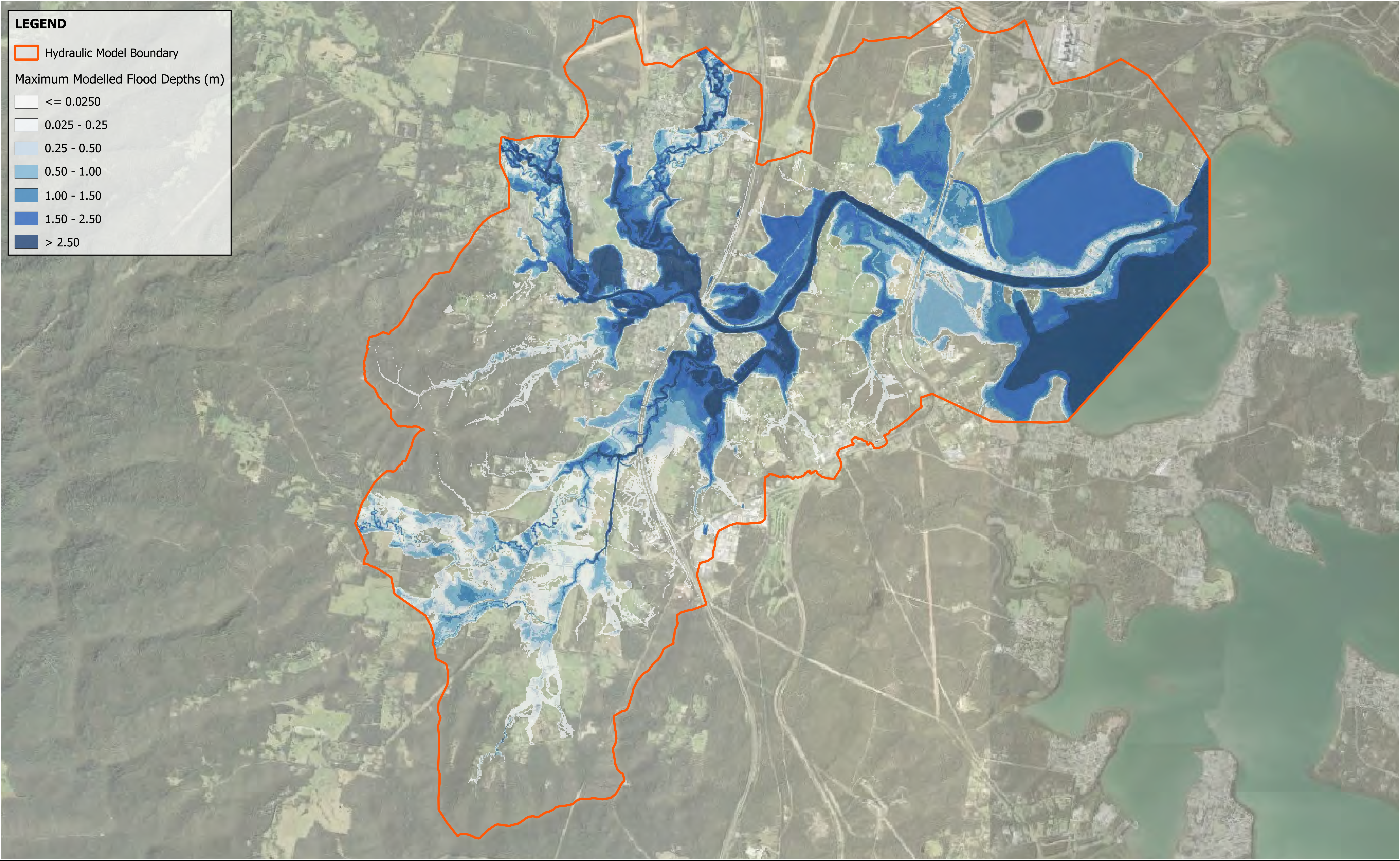
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.16: 5% AEP (20 Year ARI)

Maximum Flood Hazard Categorisation

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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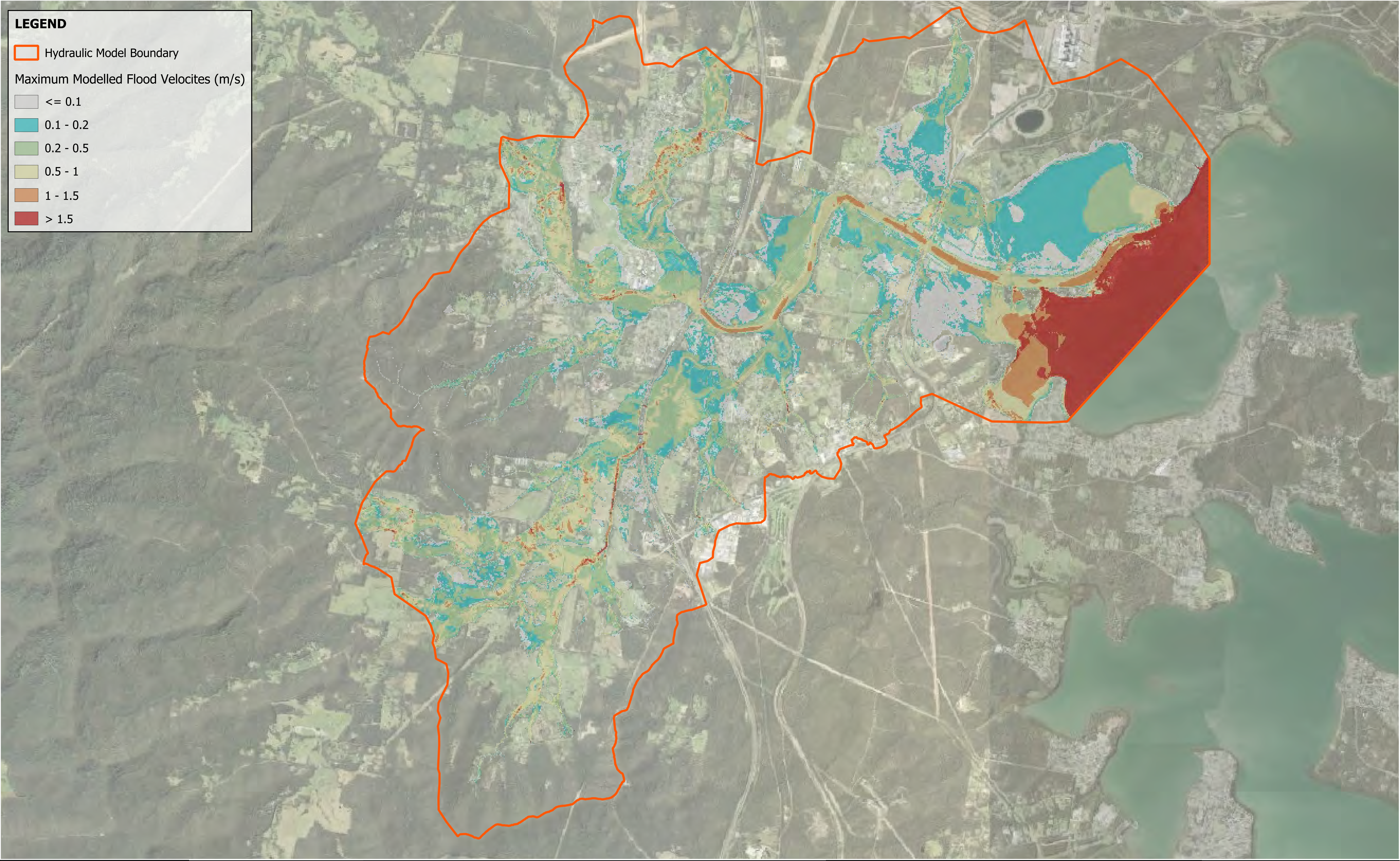
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.17: 2% AEP (50 Year ARI)

Maximum Flood Depths

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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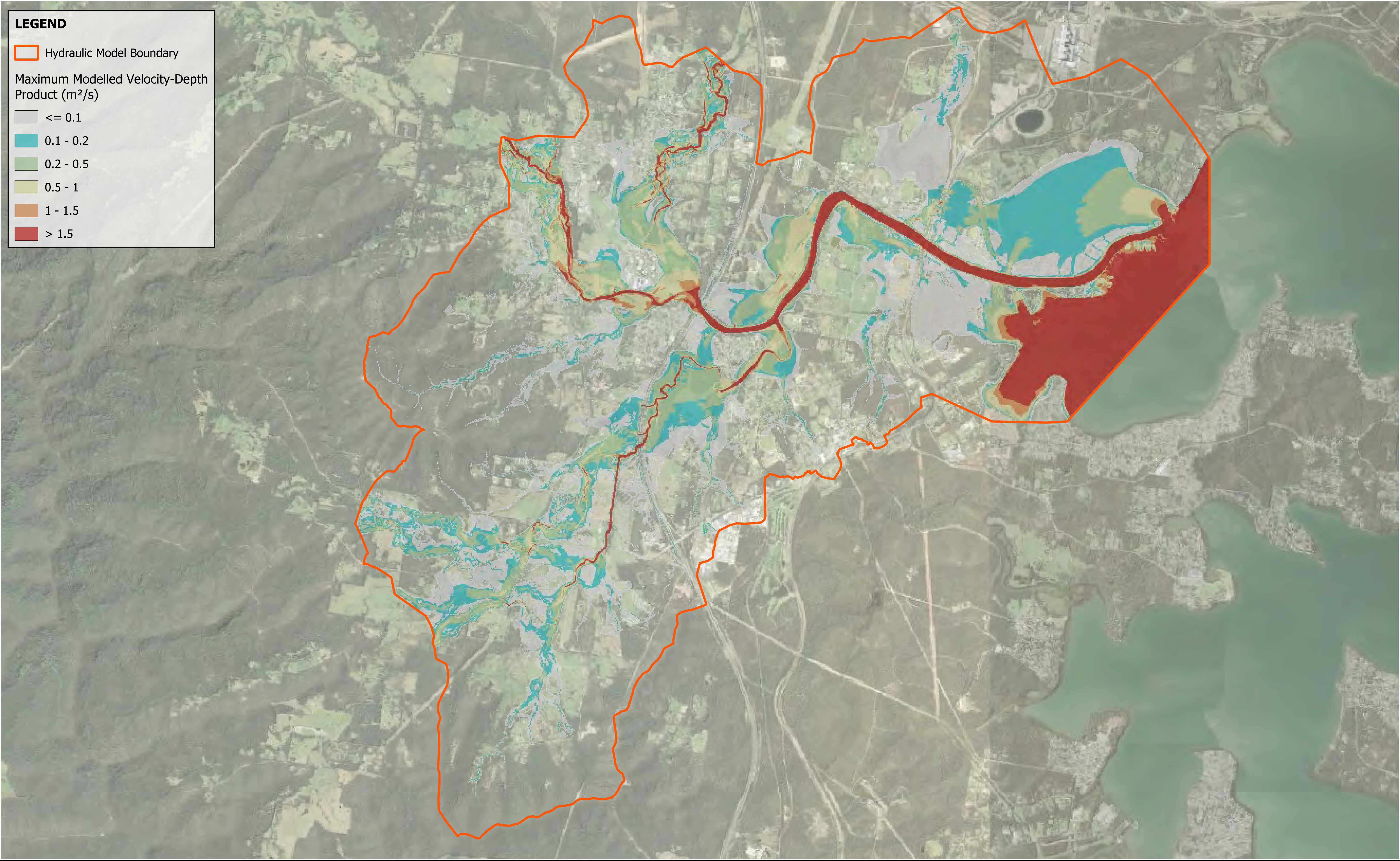
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.18: 2% AEP (50 Year ARI)

Maximum Flood Velocities

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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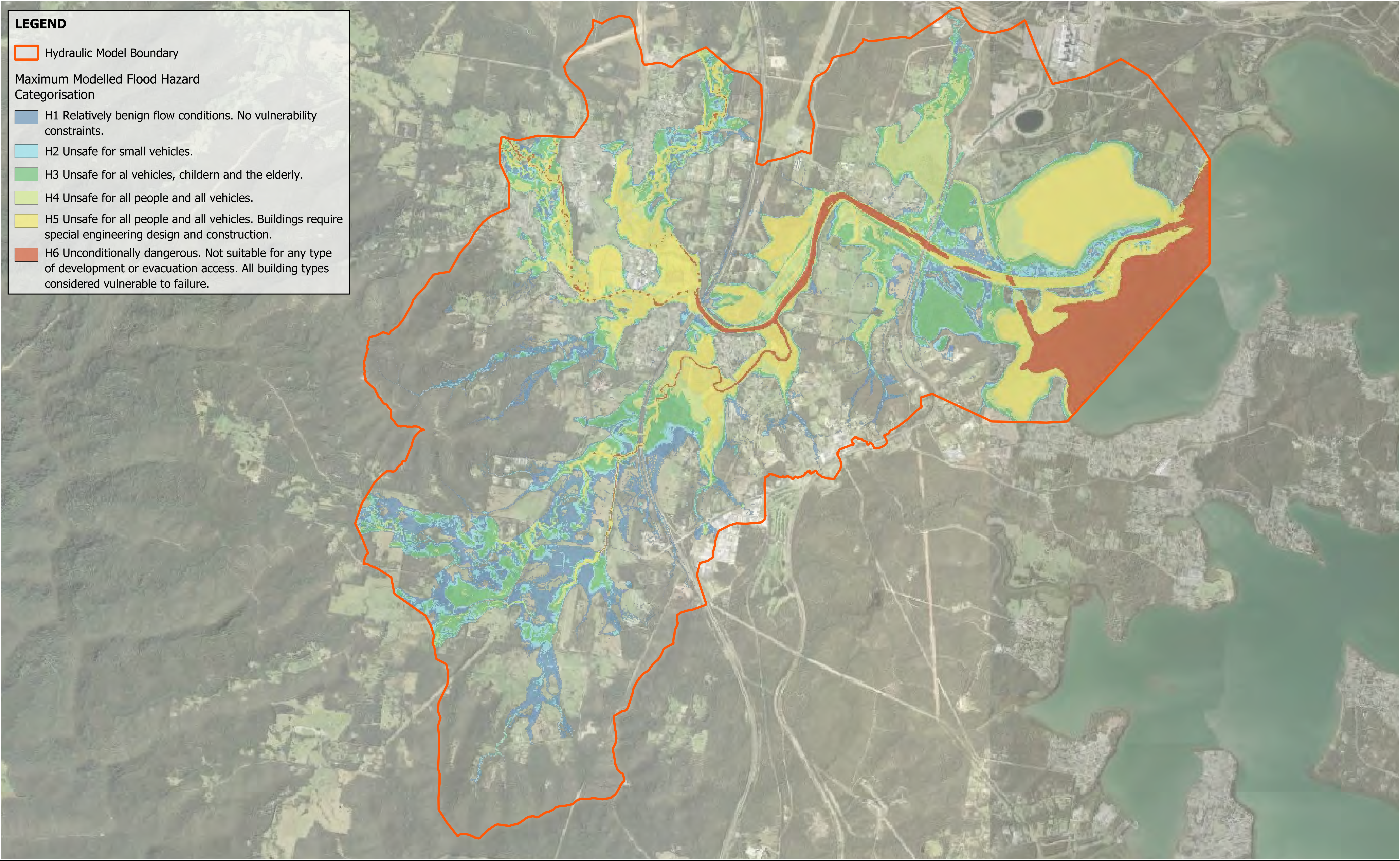
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.19: 2% AEP (50 Year ARI)

Maximum Flood Velocity- Depth Product

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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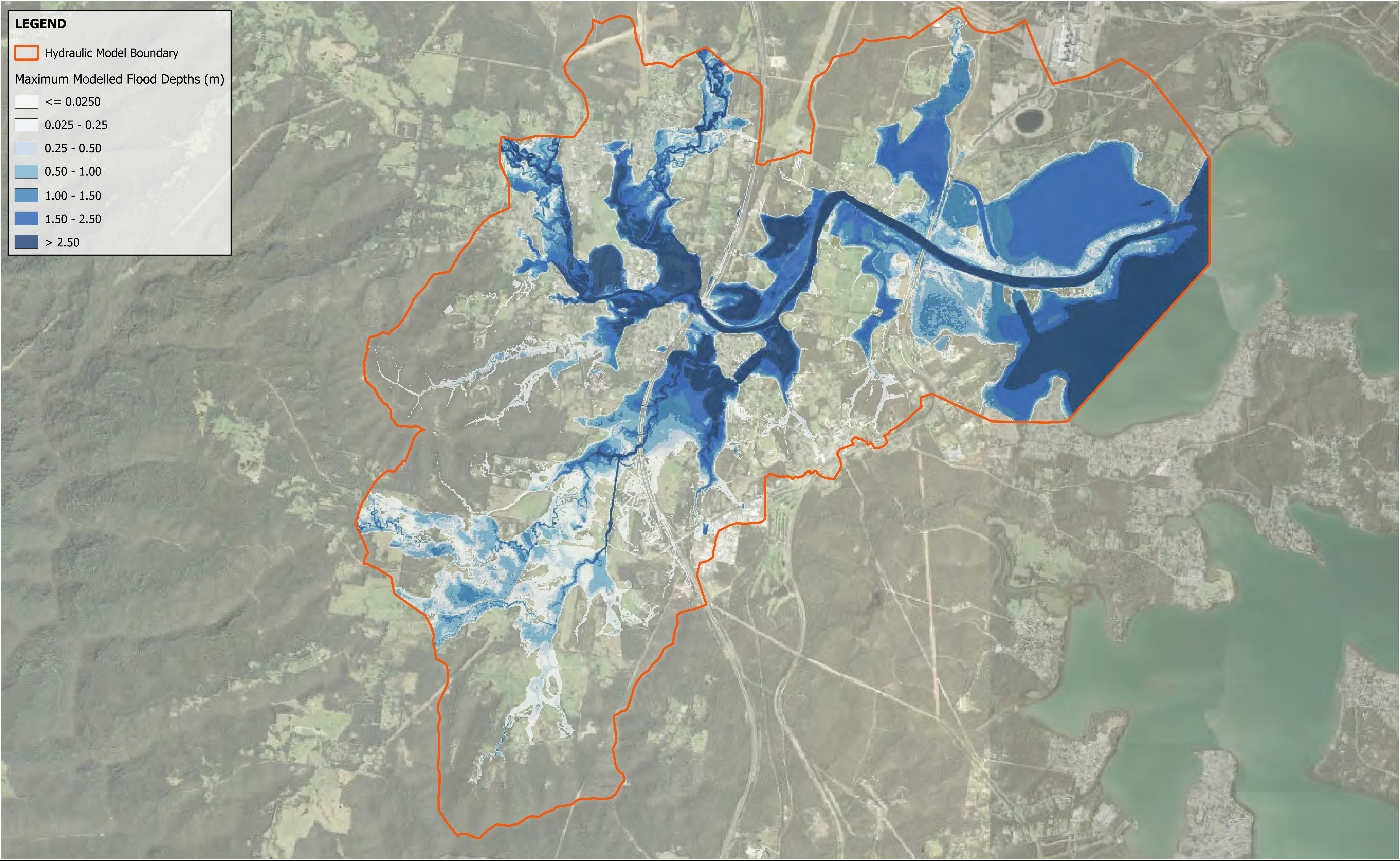
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.20: 2% AEP (50 Year ARI)

Maximum Flood Hazard Categorisation

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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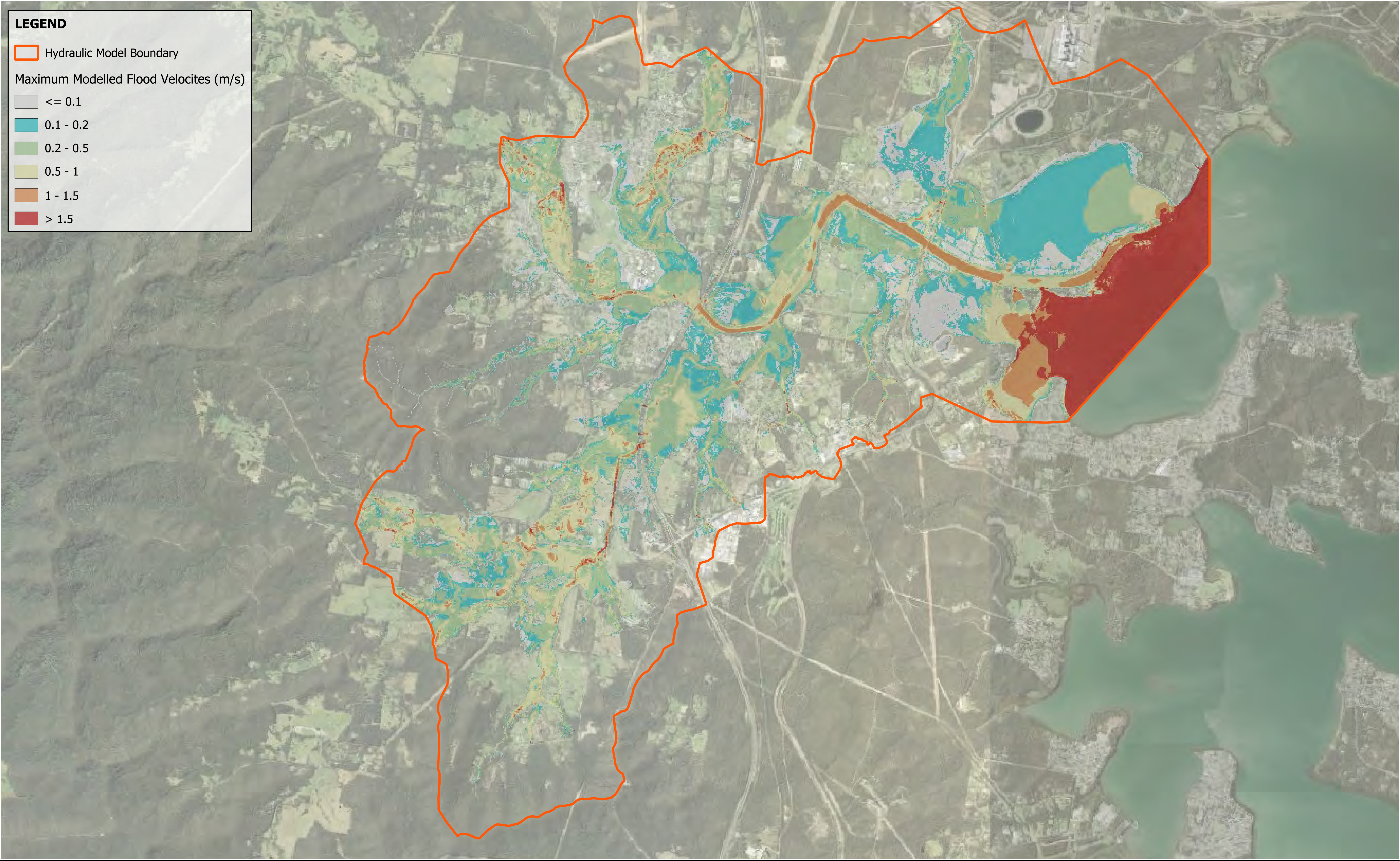
Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.21: 1% AEP (100 Year ARI)

Maximum Flood Depths

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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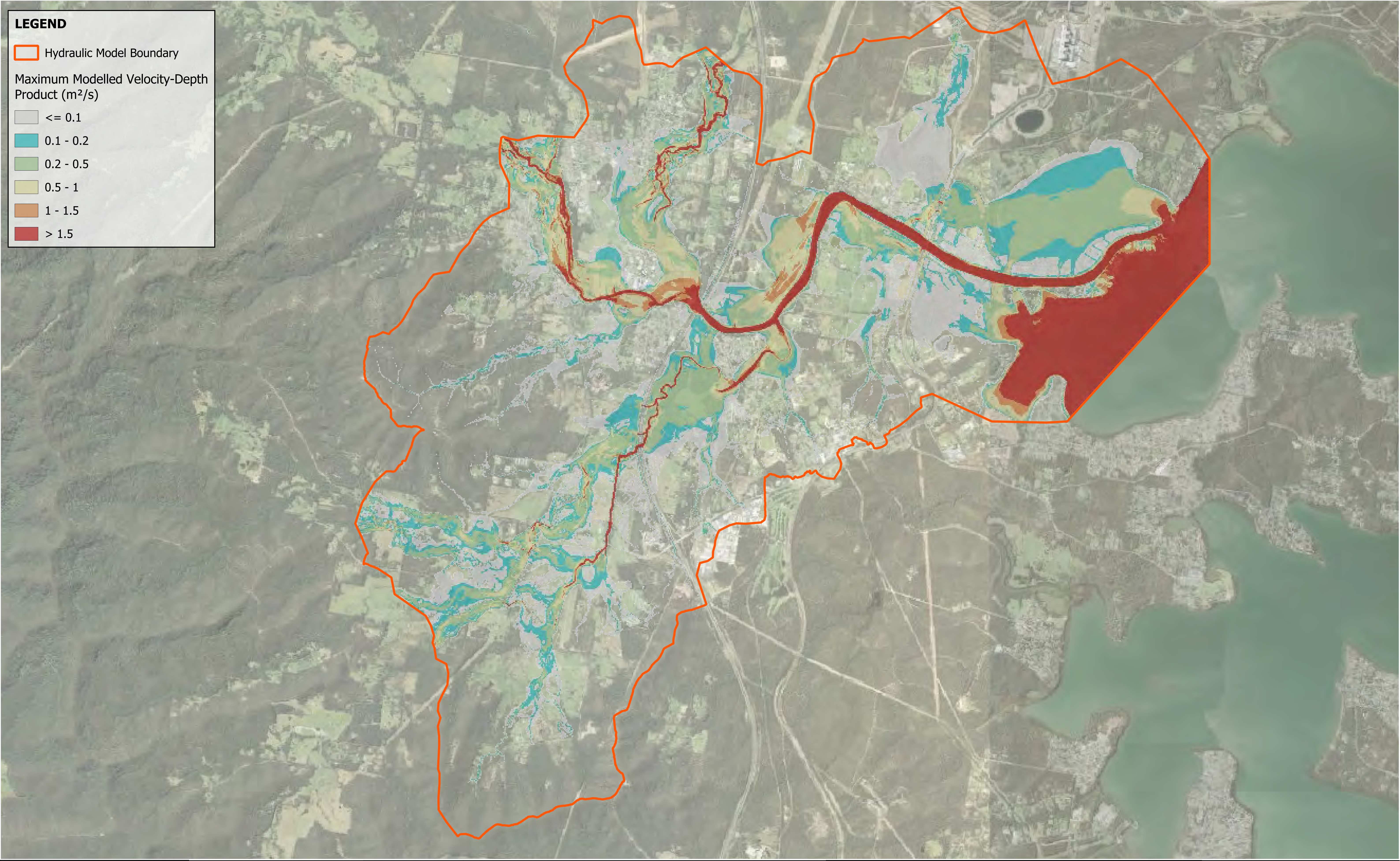
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.22: 1% AEP (100 Year ARI)

Maximum Flood Velocities

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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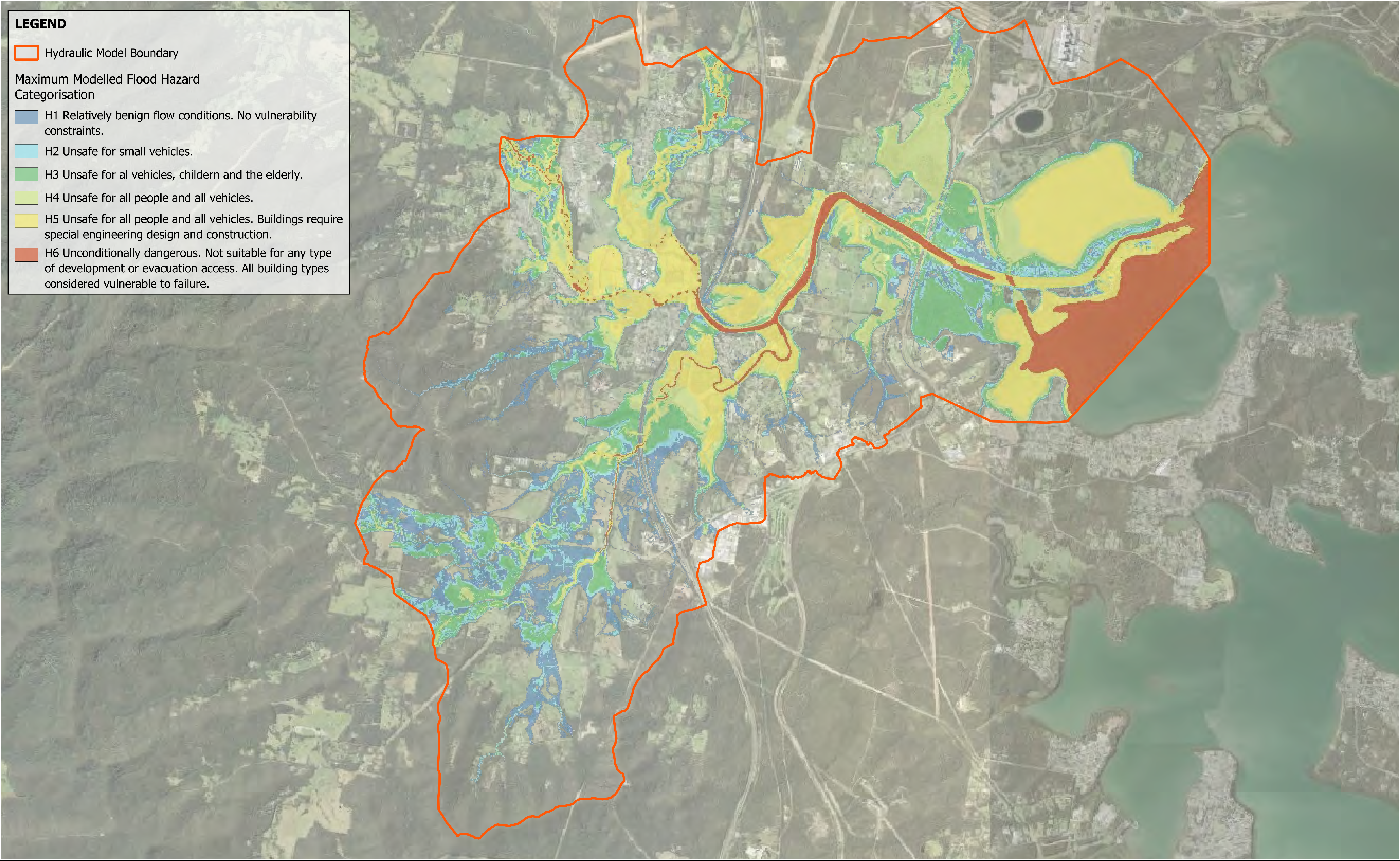
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.23: 1% AEP (100 Year ARI)

Maximum Flood Velocity- Depth Product

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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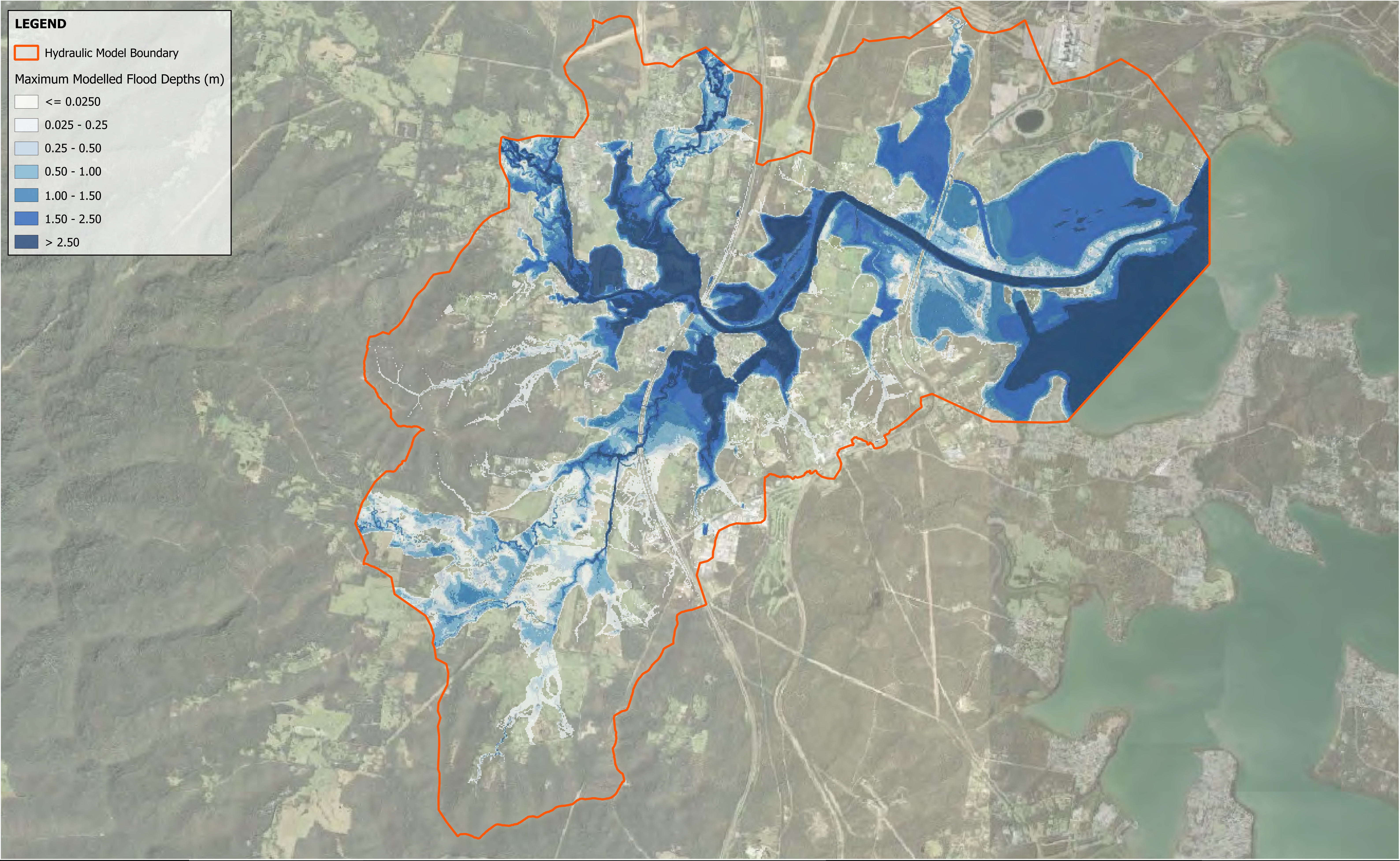
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.24: 1% AEP (100 Year ARI)

Maximum Flood Hazard Categorisation

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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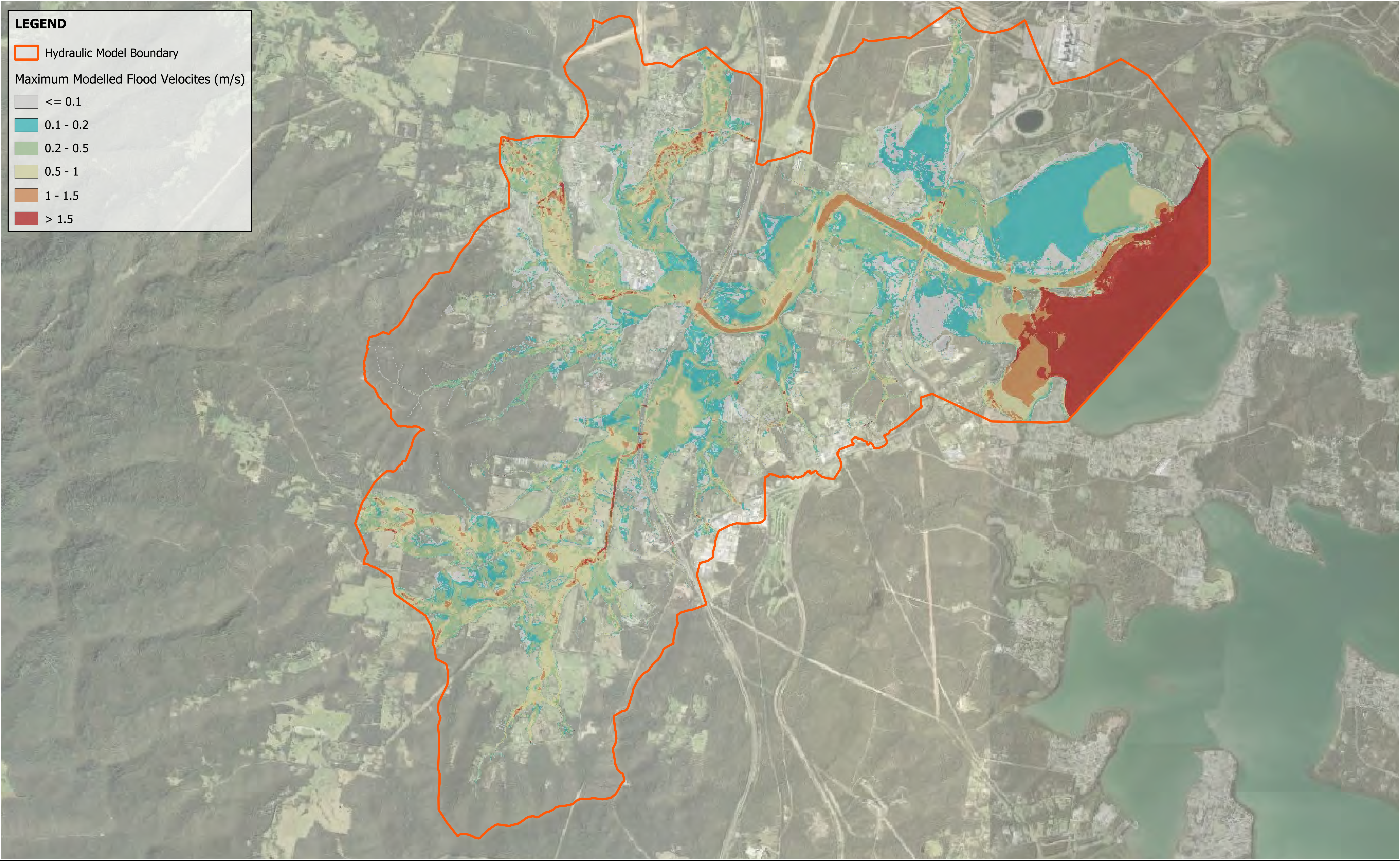
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.25: 0.5% AEP (200 Year ARI)

Maximum Flood Depths

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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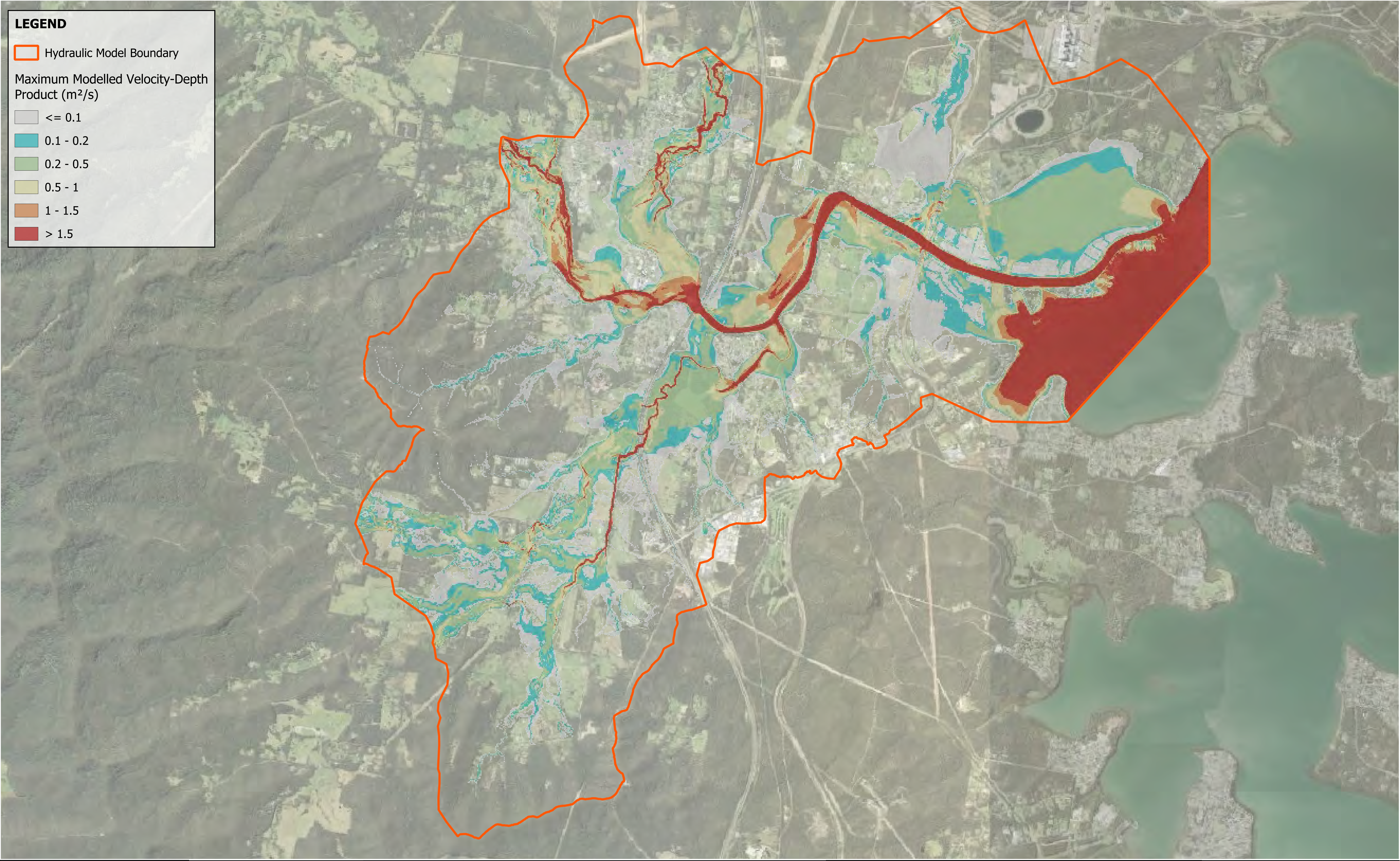
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.26: 0.5% AEP (200 Year ARI)

Maximum Flood Velocities

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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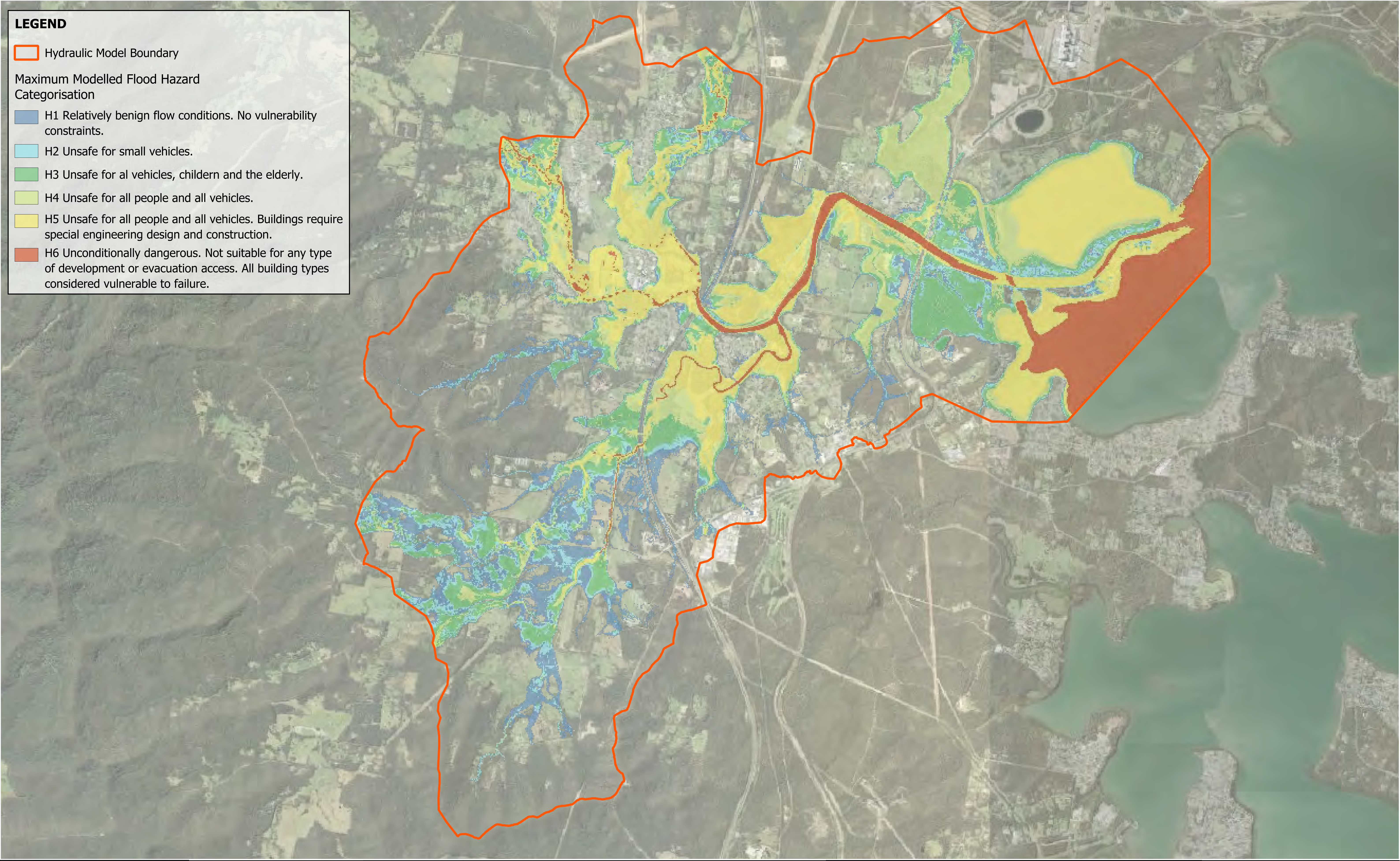
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.27: 0.5% AEP (200 Year ARI)

Maximum Flood Velocity- Depth Product

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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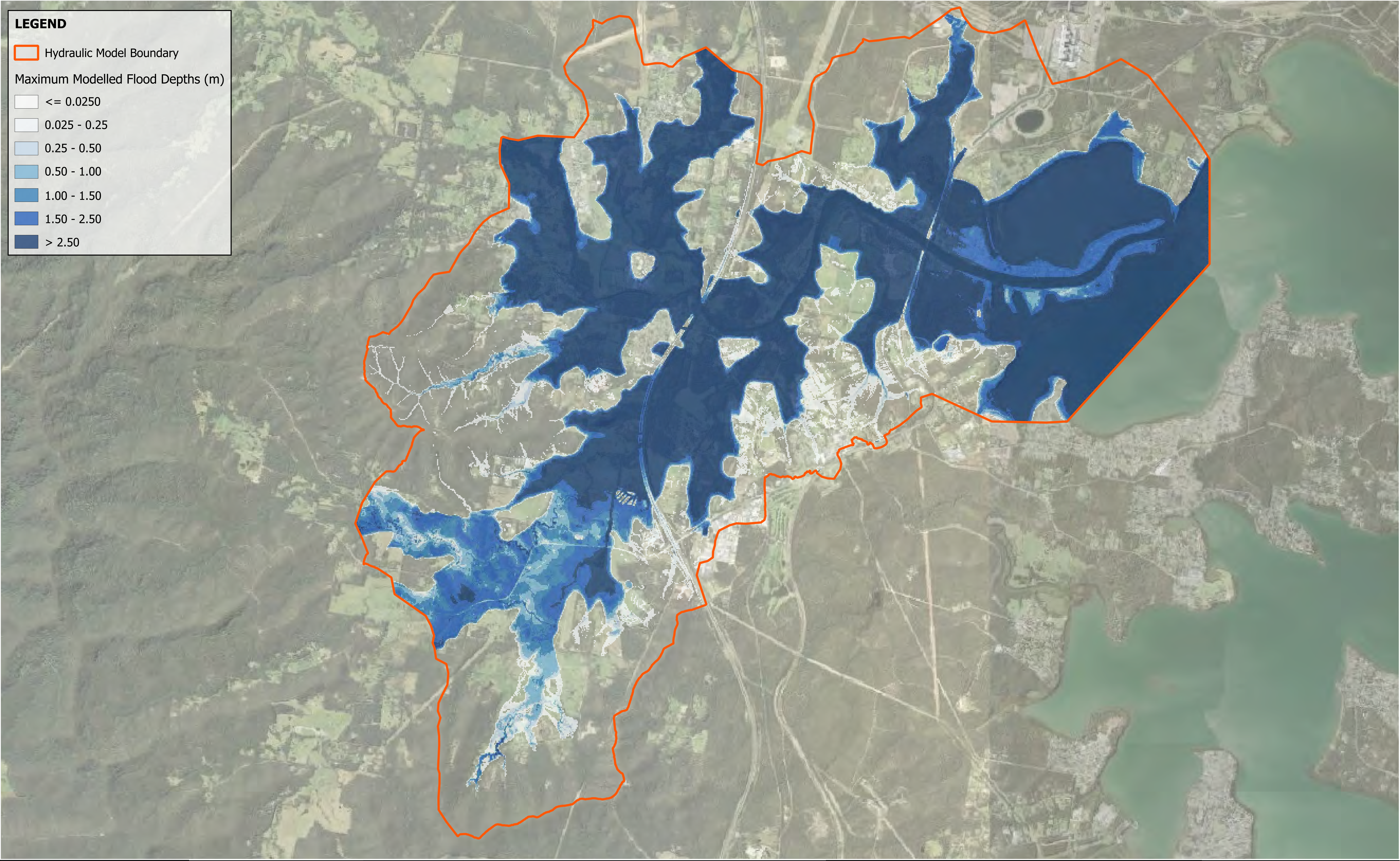
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.28: 0.5% AEP (200 Year ARI)

Maximum Flood Hazard Categorisation

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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Scale in metres (1:42,500@ A3)

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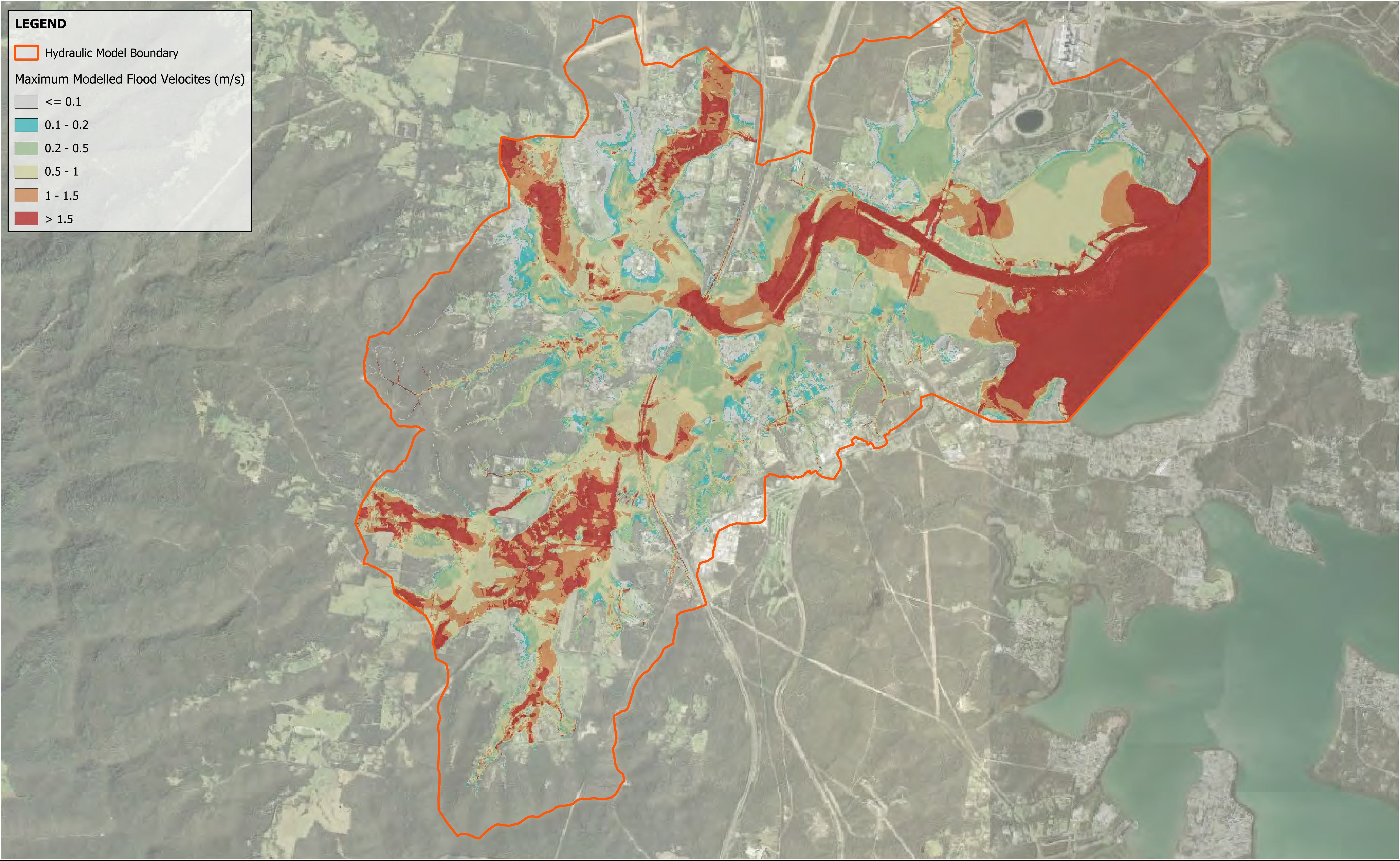
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.29: Probable Maximum Flood (PMF)

Maximum Flood Depths

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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N

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Map Projection: Tranverse Mercator
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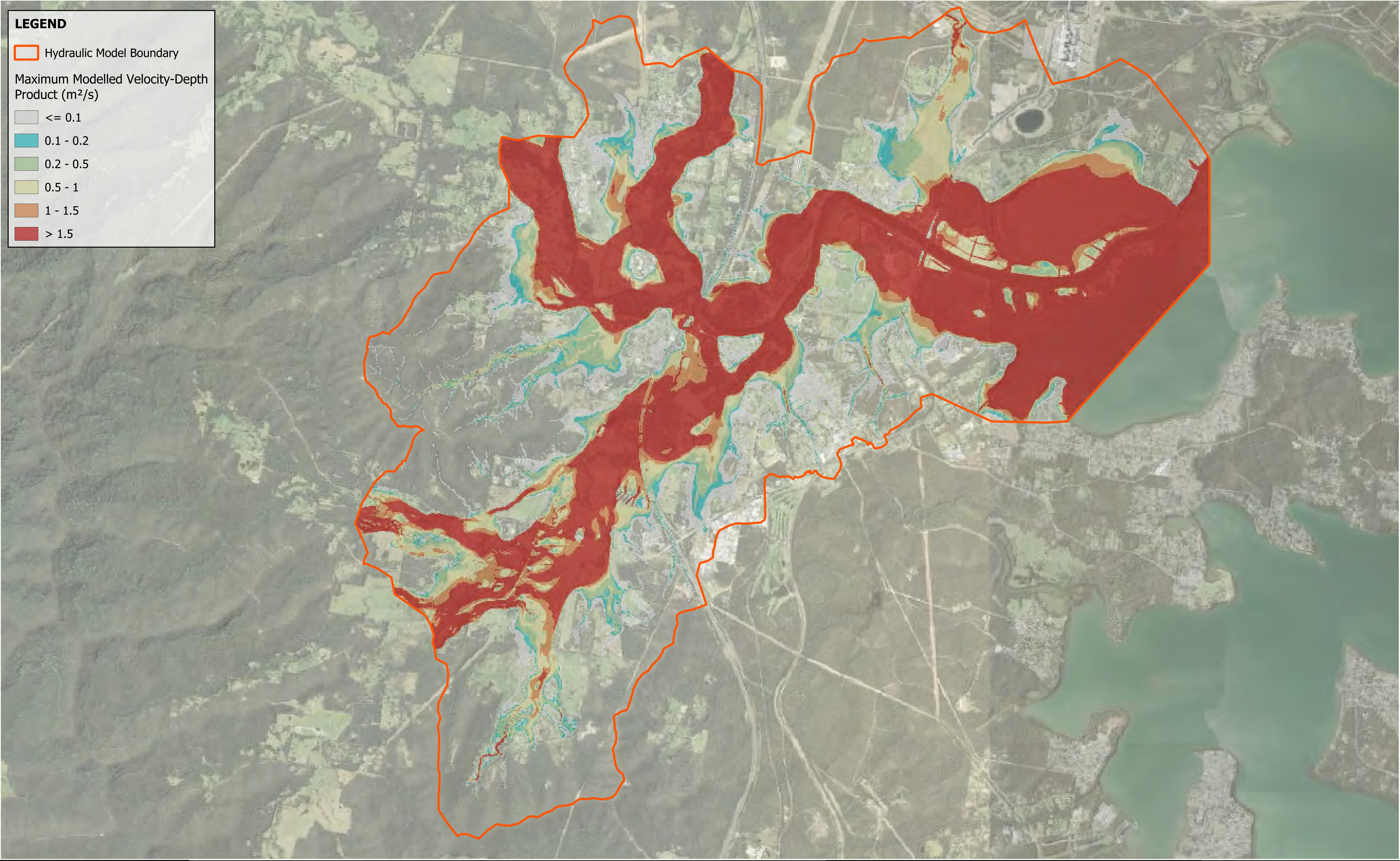
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.30: Probable Maximum Flood (PMF)

Maximum Flood Velocities

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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N

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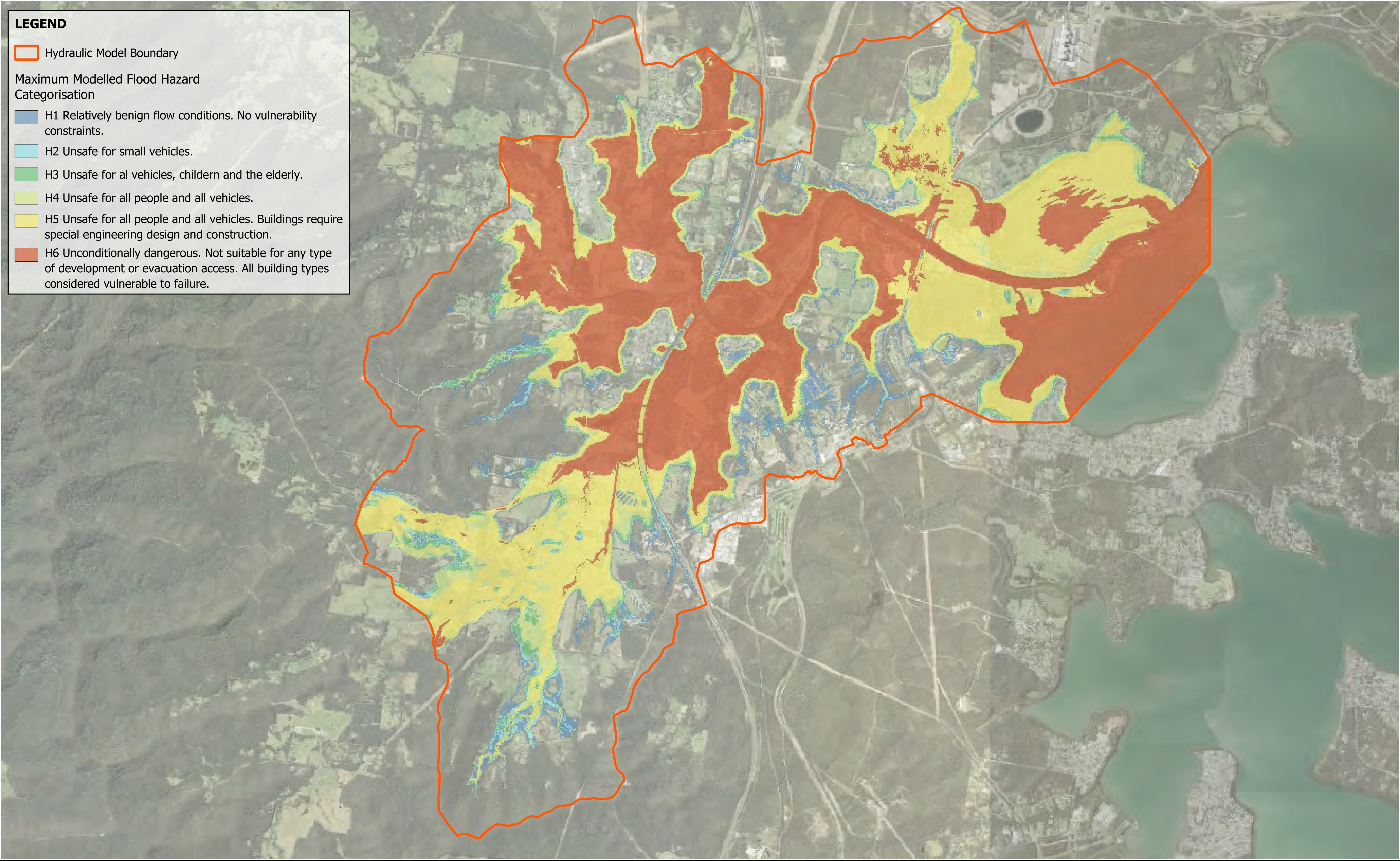
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.31: Probable Maximum Flood (PMF)

Maximum Flood Velocity- Depth Product

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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N

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Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
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Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure B.32: Probable Maximum Flood (PMF)

Maximum Flood Hazard Categorisation

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Revision: 0
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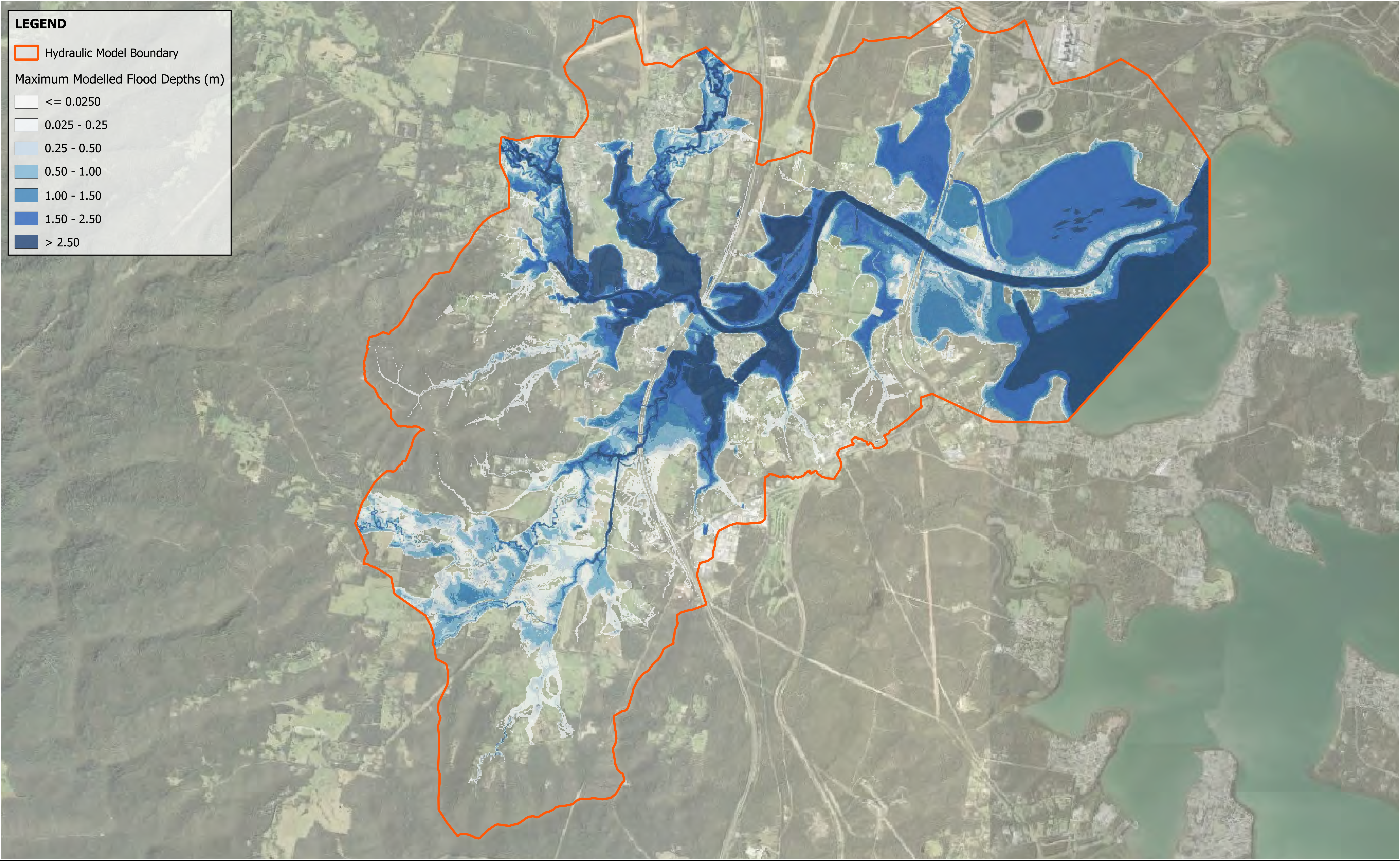
Date: 31/7/2024

APPENDIX C: FLOOD MAPPING – SENSITIVITY ANALYSIS



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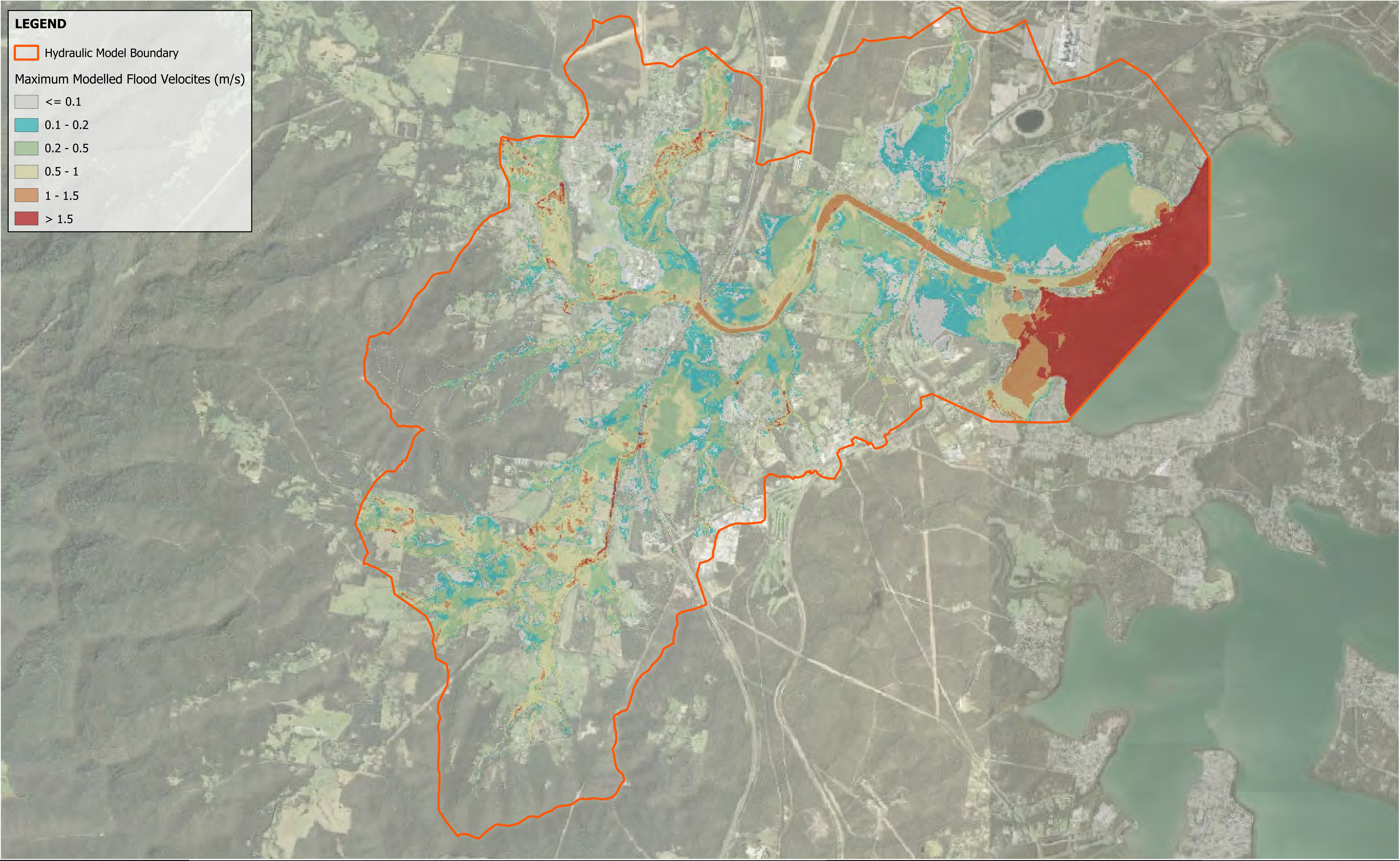
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.1: 1% AEP (100 Year ARI) - Climate Change

10% Rainfall Intensity Increase - Modelled Flood Depths

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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Map Projection: Tranverse Mercator
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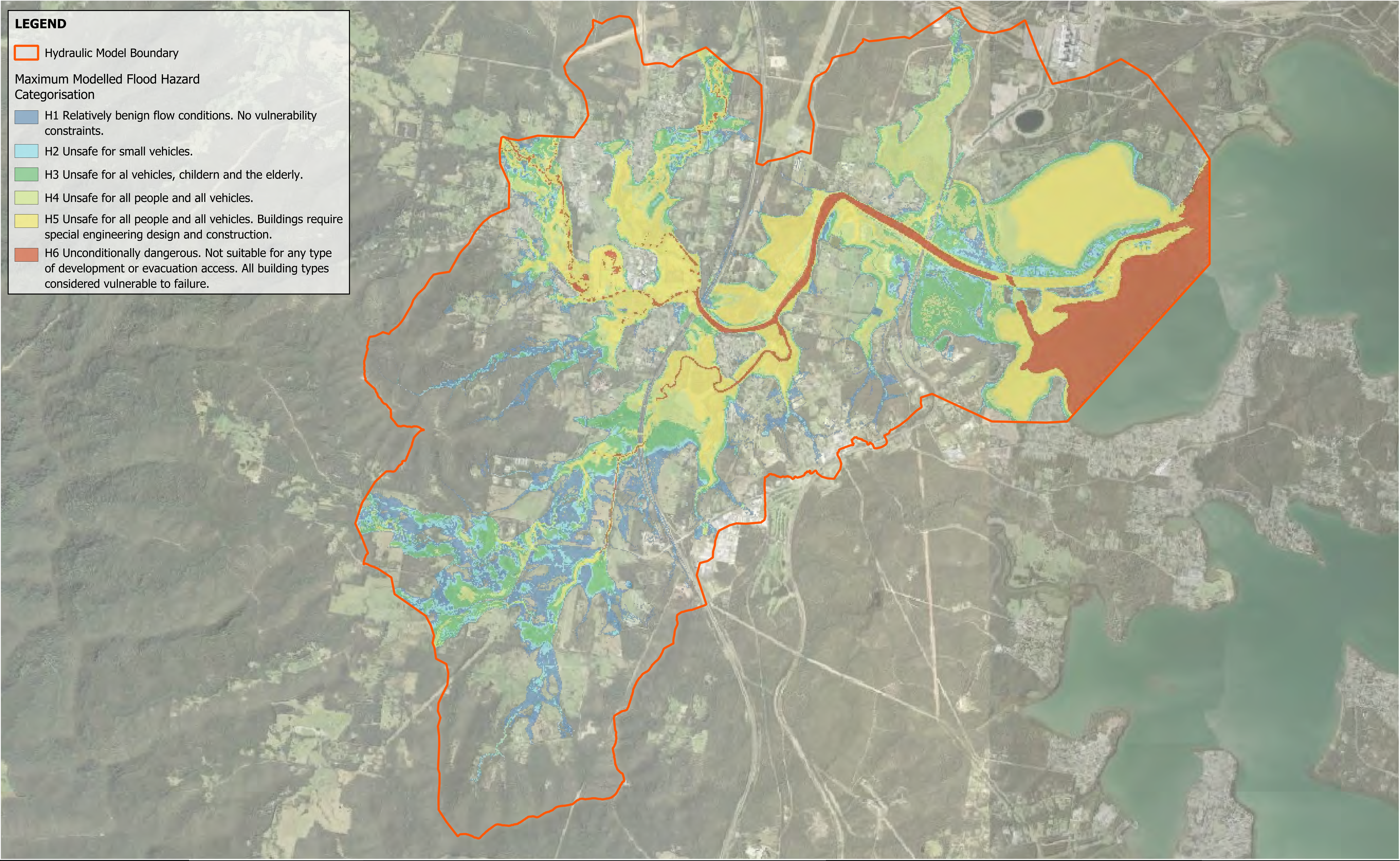
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.2: 1% AEP (100 Year ARI) - Climate Change
10% Rainfall Intensity Increase - Modelled Flood Velocity

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.3: 1% AEP (100 Year ARI) - Climate Change
10% Rainfall Intensity Increase - Modelled Flood Hazard Categorisation

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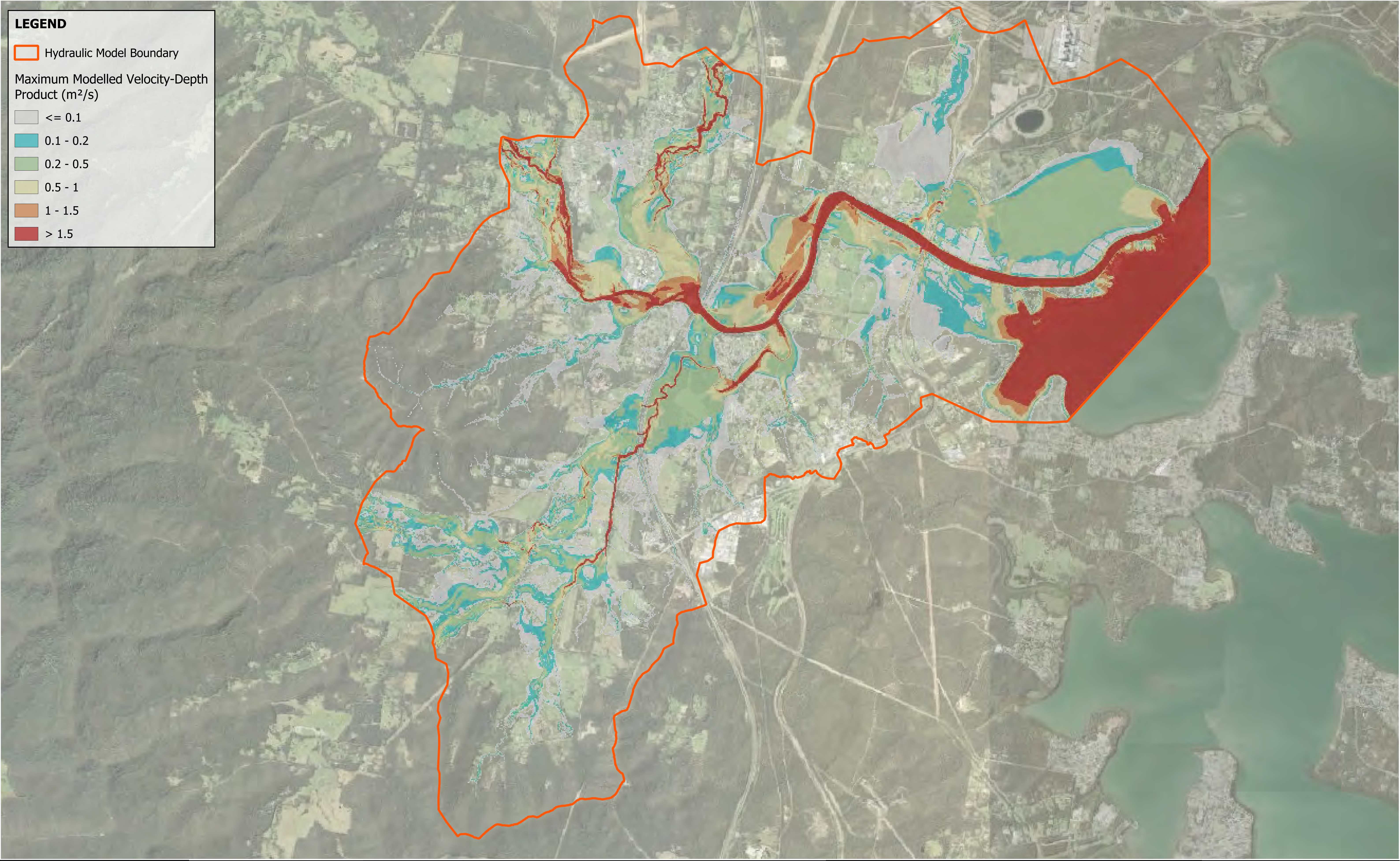
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
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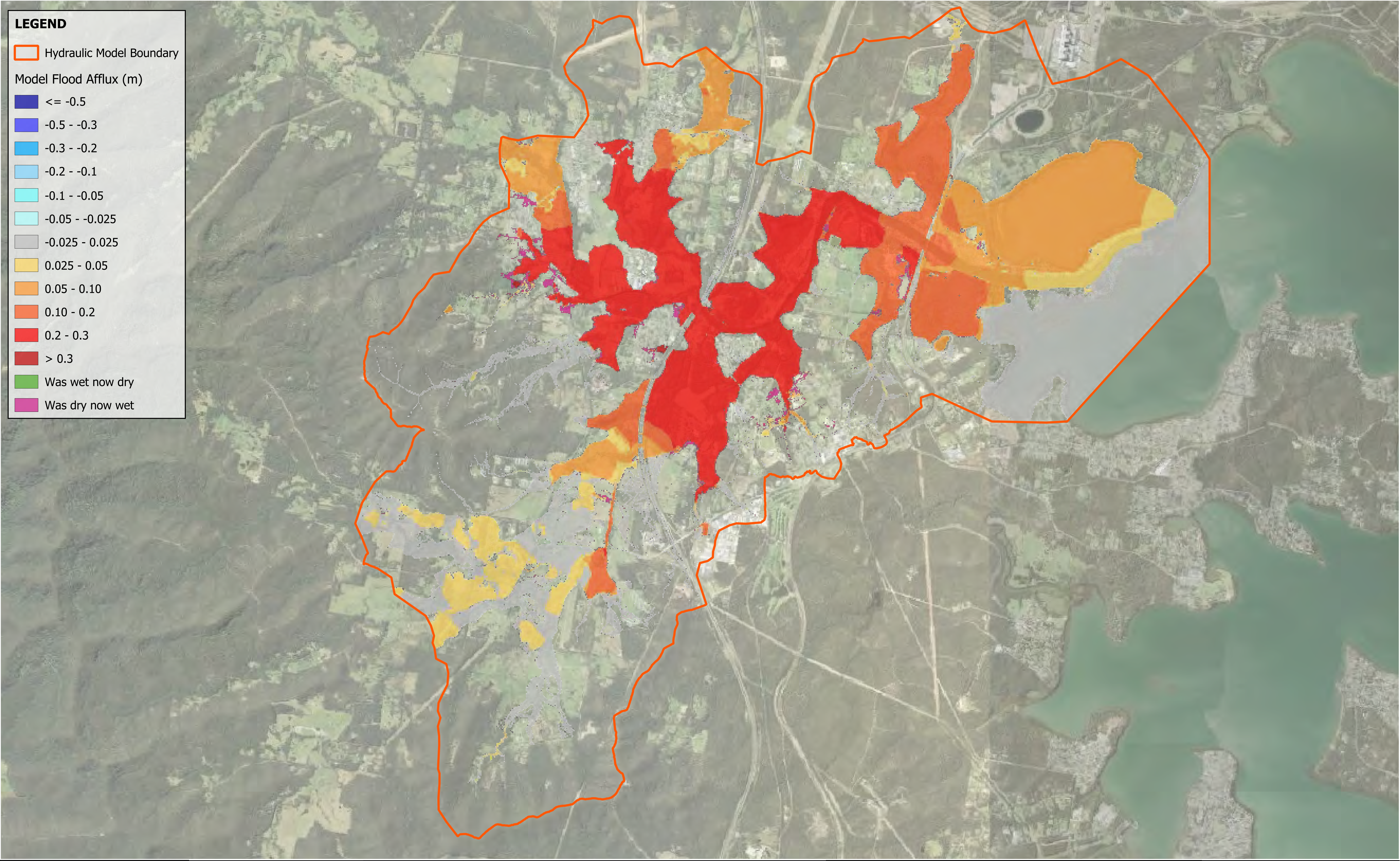
Figure C.4: 1% AEP (100 Year ARI) - Climate Change
10% Rainfall Intensity Increase - Modelled Flood Velocity- Depth Product

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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Map Projection: Tranverse Mercator
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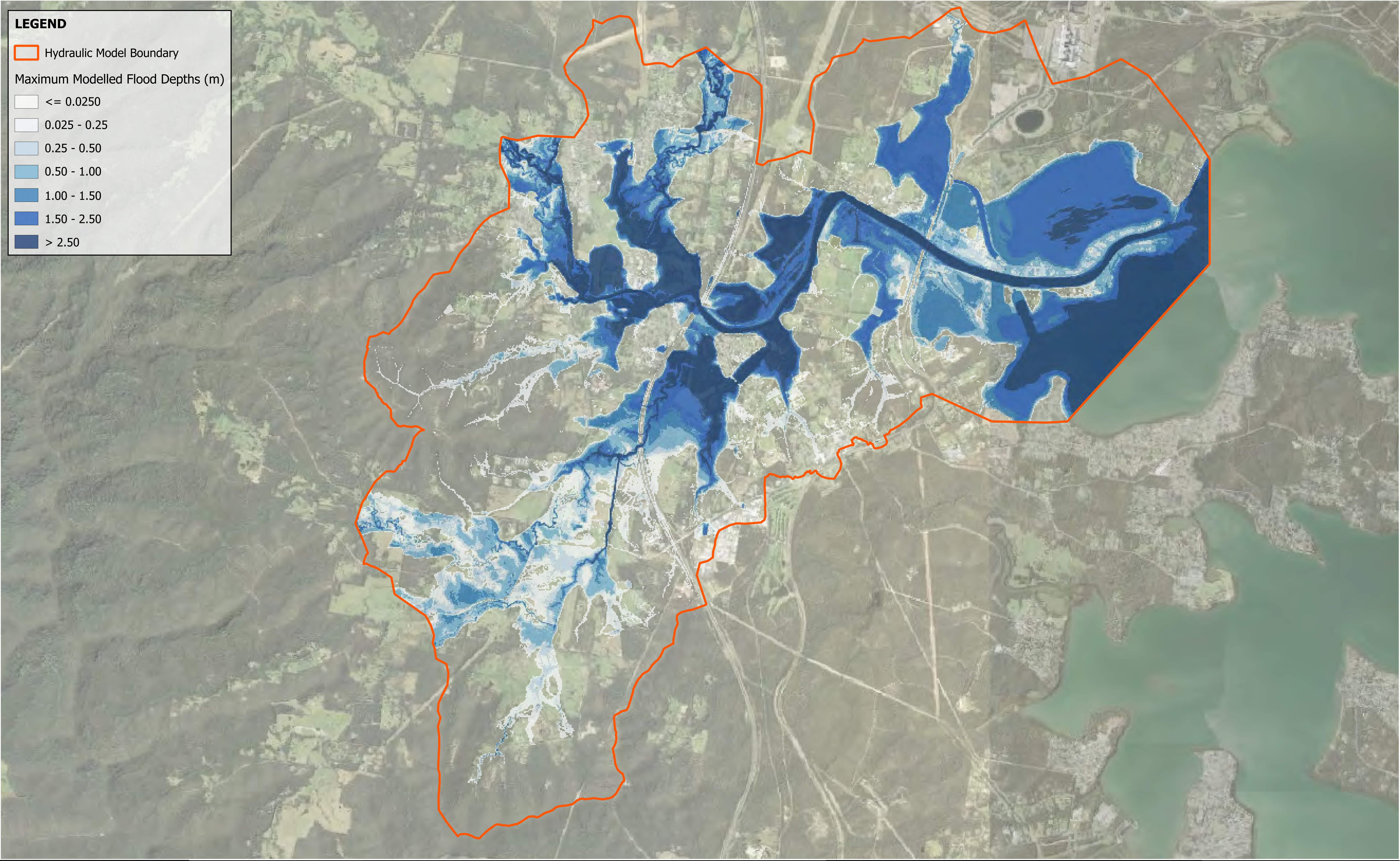
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.5: 1% AEP (100 Year ARI) - Climate Change
Modelled Flood Afflux (Basecase vs 10% Rainfall Intensity Increase)

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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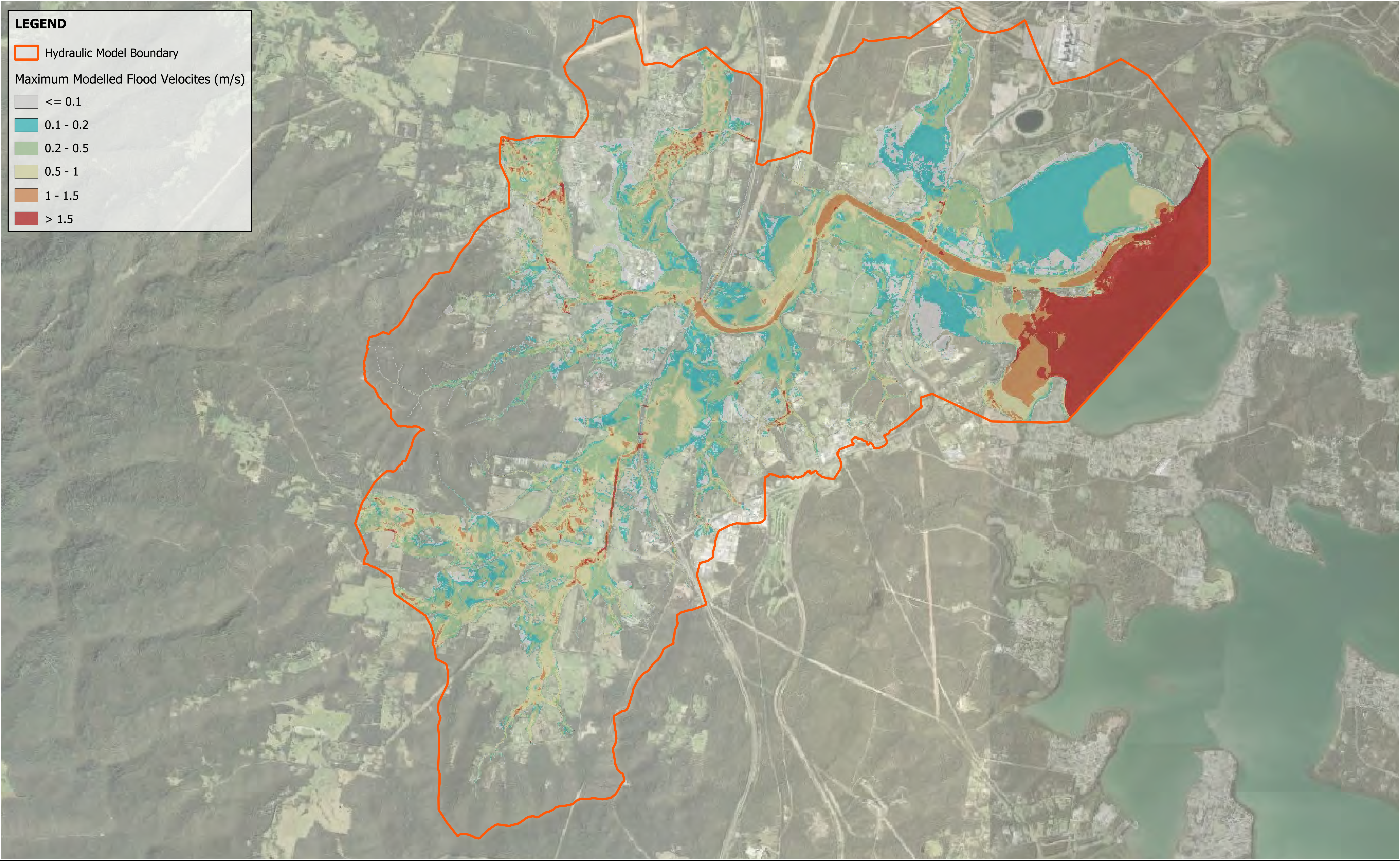
Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.6: 1% AEP (100 Year ARI) - Climate Change
20% Rainfall Intensity Increase - Modelled Flood Depths

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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Map Projection: Tranverse Mercator
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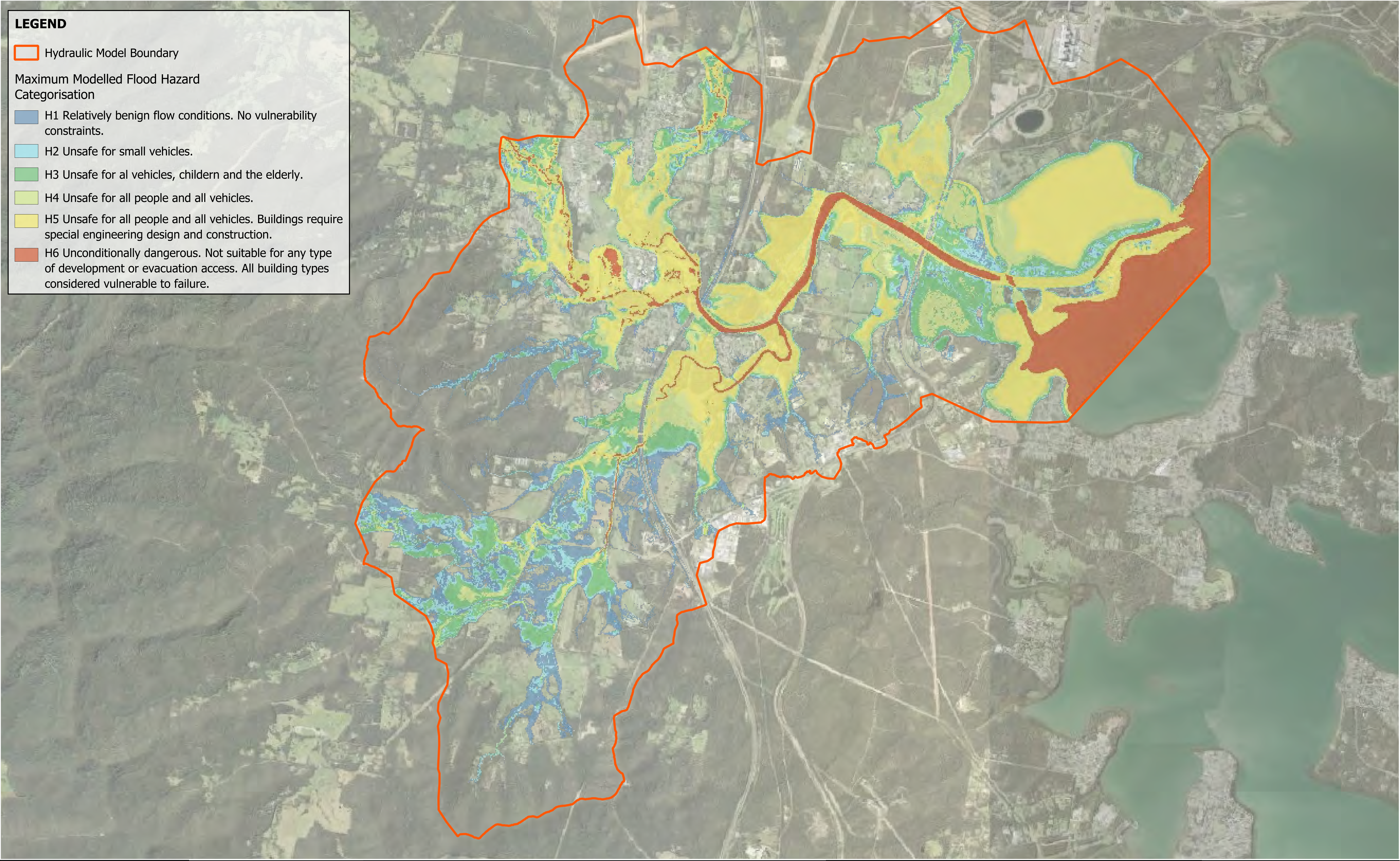
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.7: 1% AEP (100 Year ARI) - Climate Change
20% Rainfall Intensity Increase - Modelled Flood Velocity

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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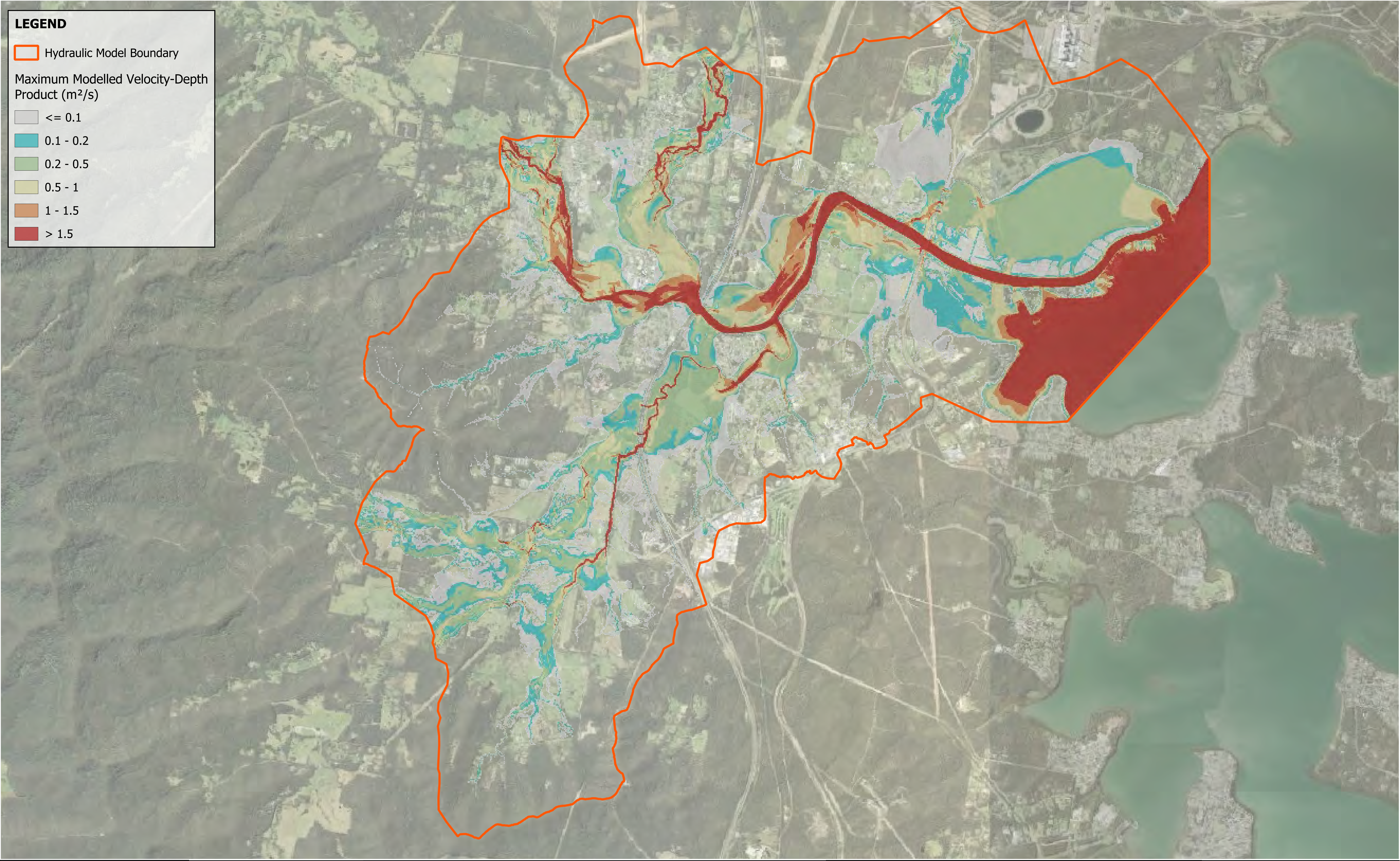
Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.8: 1% AEP (100 Year ARI) - Climate Change

20% Rainfall Intensity Increase - Modelled Flood Hazard Categorisation

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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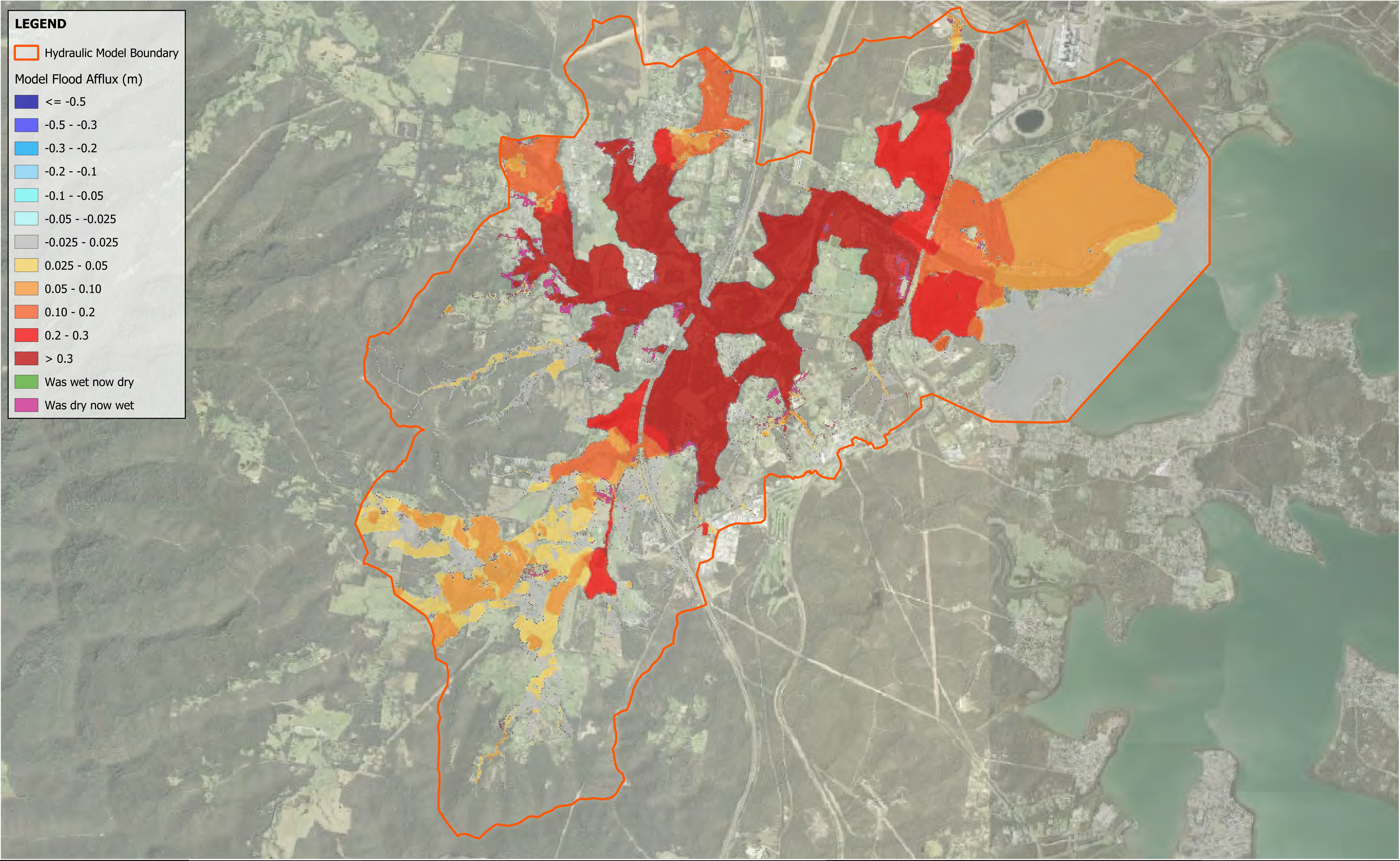
Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.9: 1% AEP (100 Year ARI) - Climate Change
20% Rainfall Intensity Increase - Modelled Flood Velocity- Depth Product

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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Map Projection: Tranverse Mercator
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Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.10: 1% AEP (100 Year ARI) - Climate Change

Modelled Flood Afflux (Basecase vs 20% Rainfall Intensity Increase)

Job Number: NC2006_001
Revision: 0
Drawn: IR
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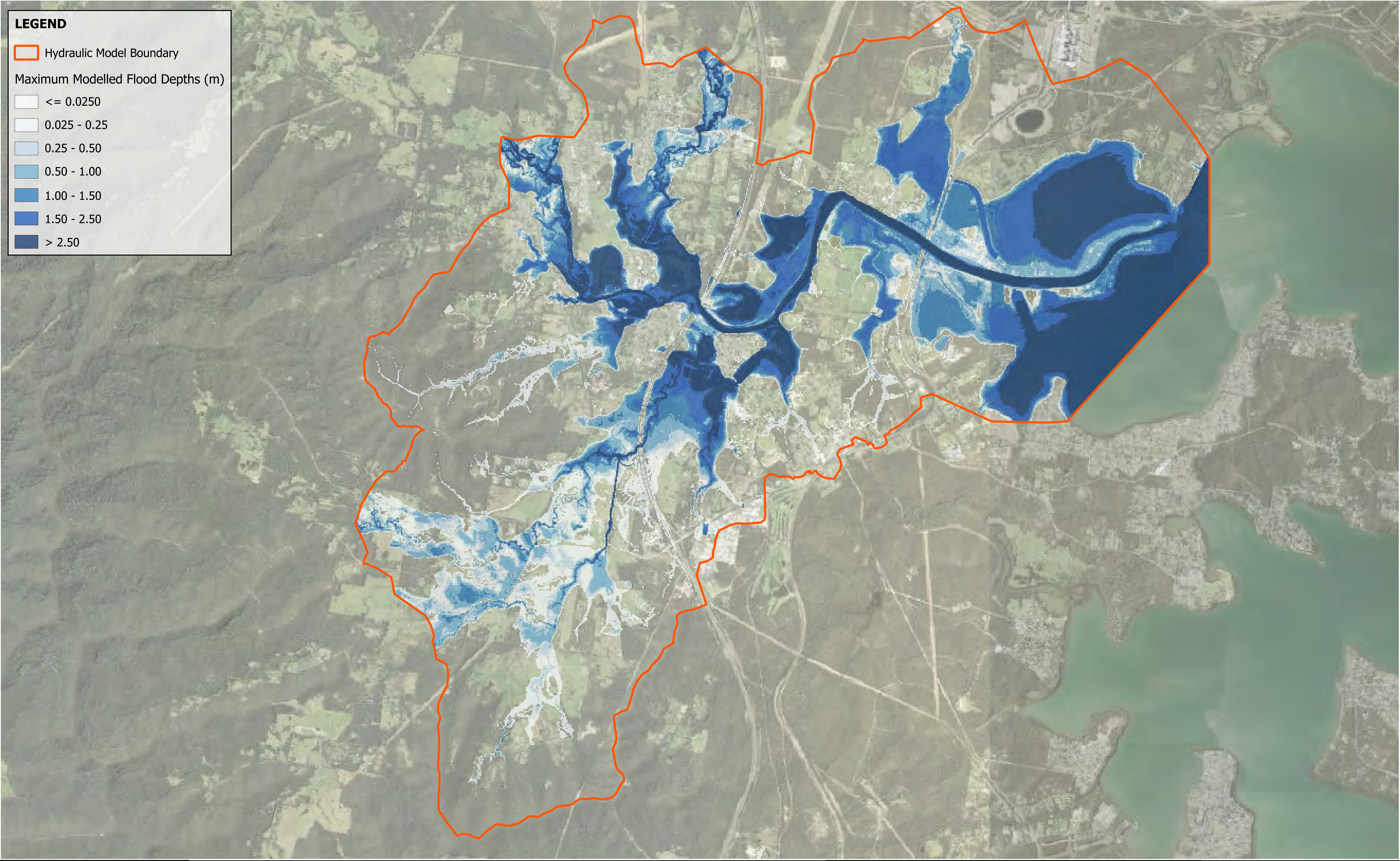

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Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.11: 1% AEP (100 Year ARI) - Climate Change

Sea Level Rise (0.5m) - Modelled Flood Depths

Job Number: NC2006_001
Revision: 0
Drawn: IR
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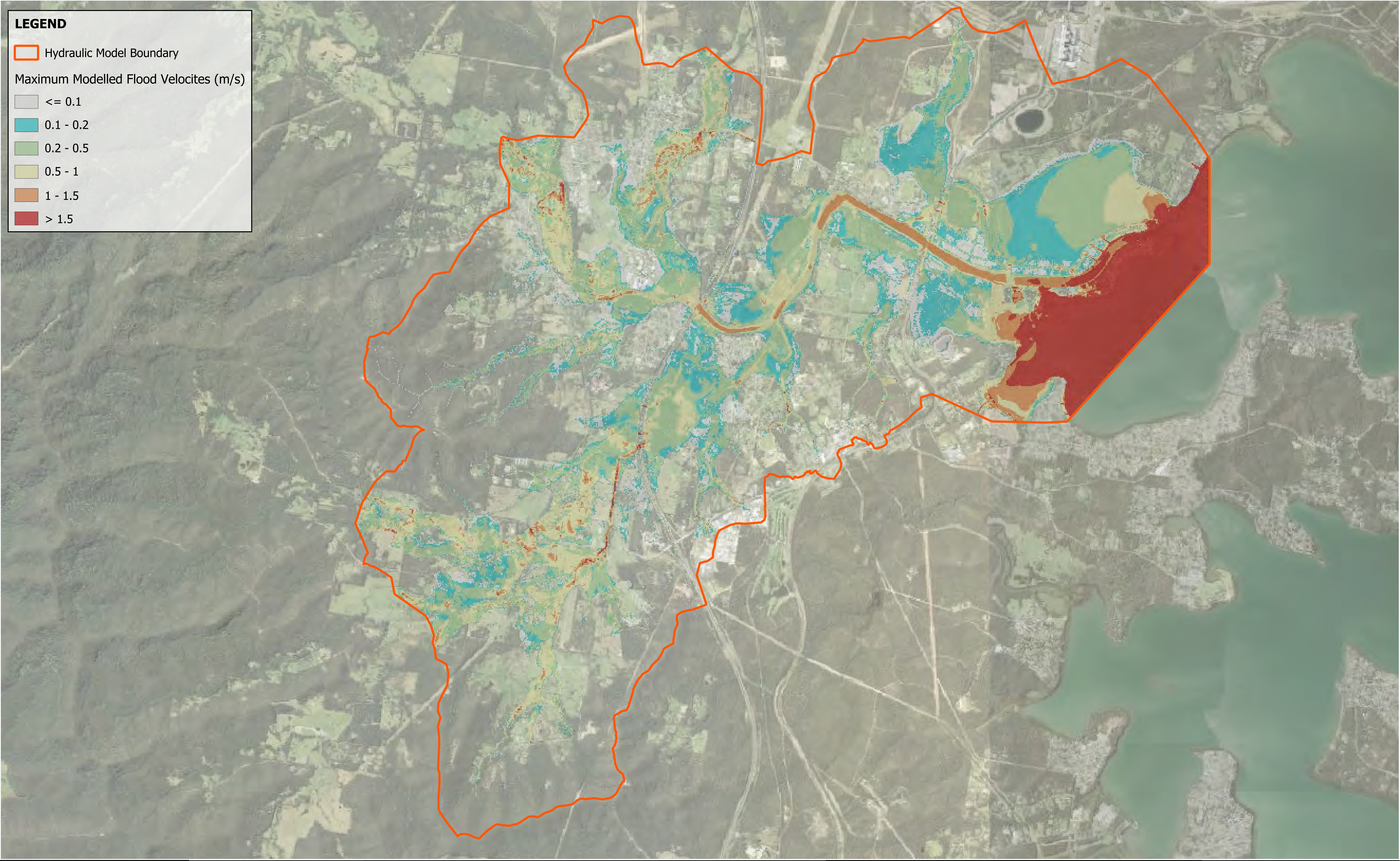
Date: 31/7/2024



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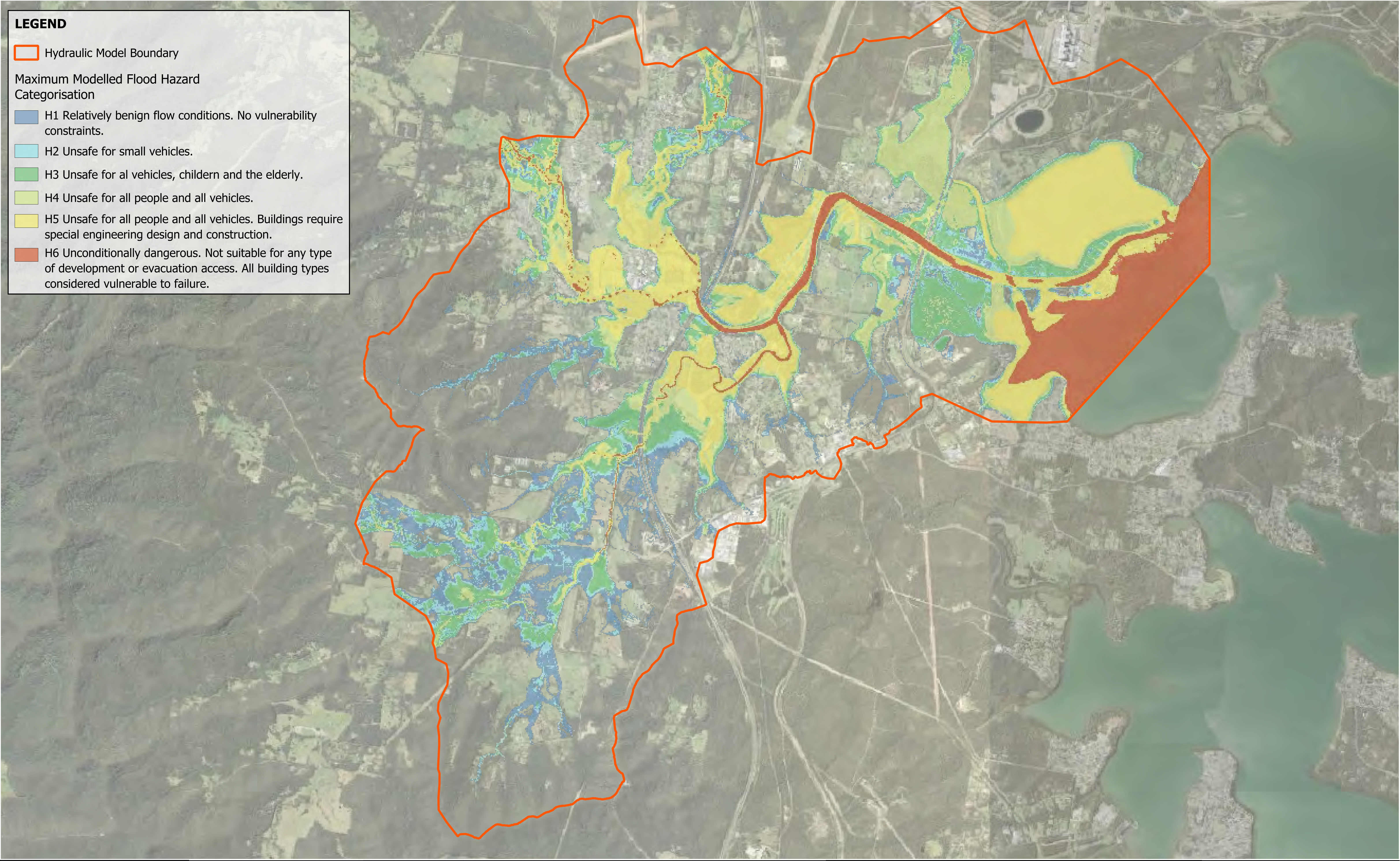
Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.12: 1% AEP (100 Year ARI) - Climate Change

Sea Level Rise (0.5m) - Modelled Flood Velocity

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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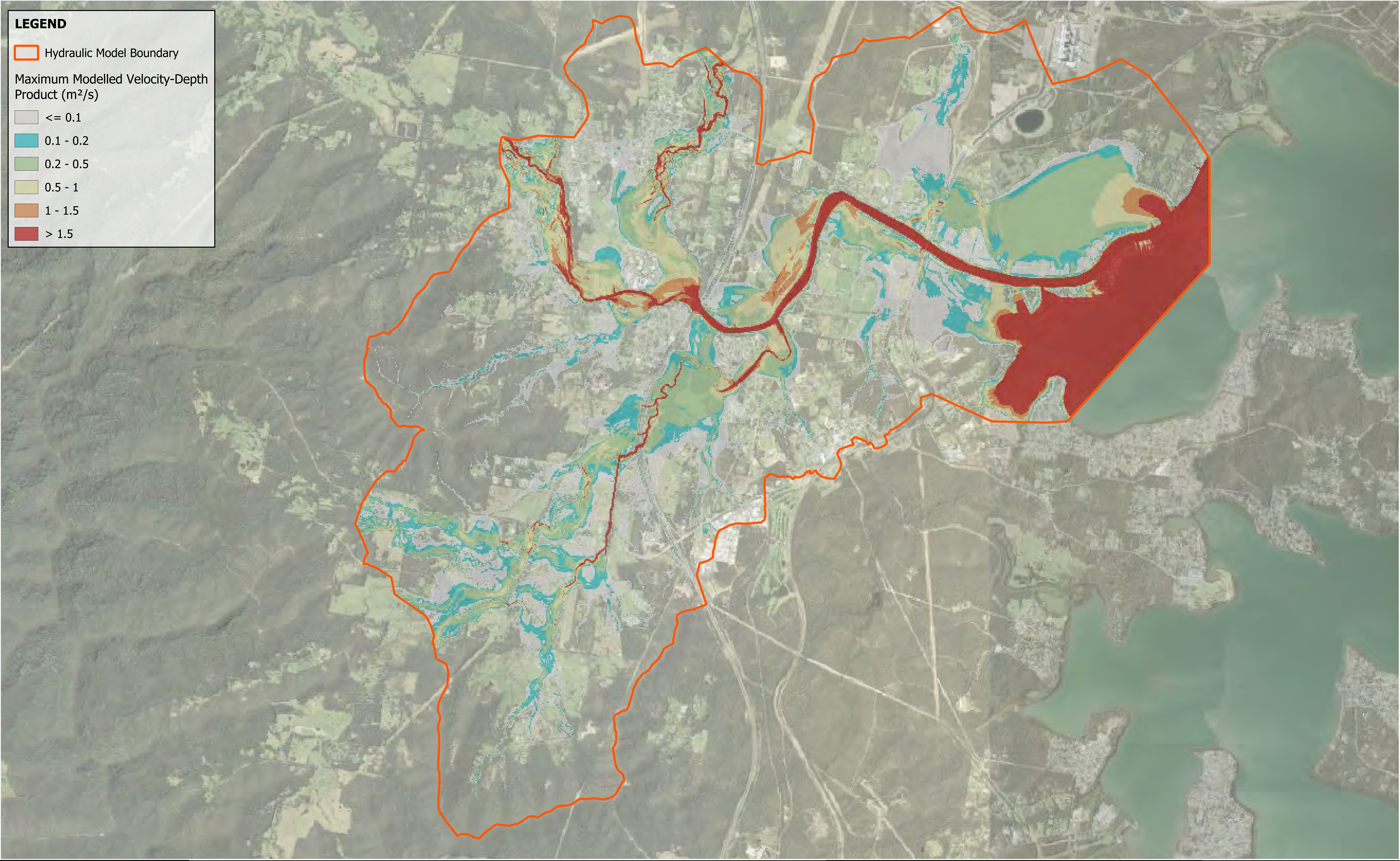
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.13: 1% AEP (100 Year ARI) - Climate Change

Sea Level Rise (0.5m) - Modelled Flood Hazard Categorisation

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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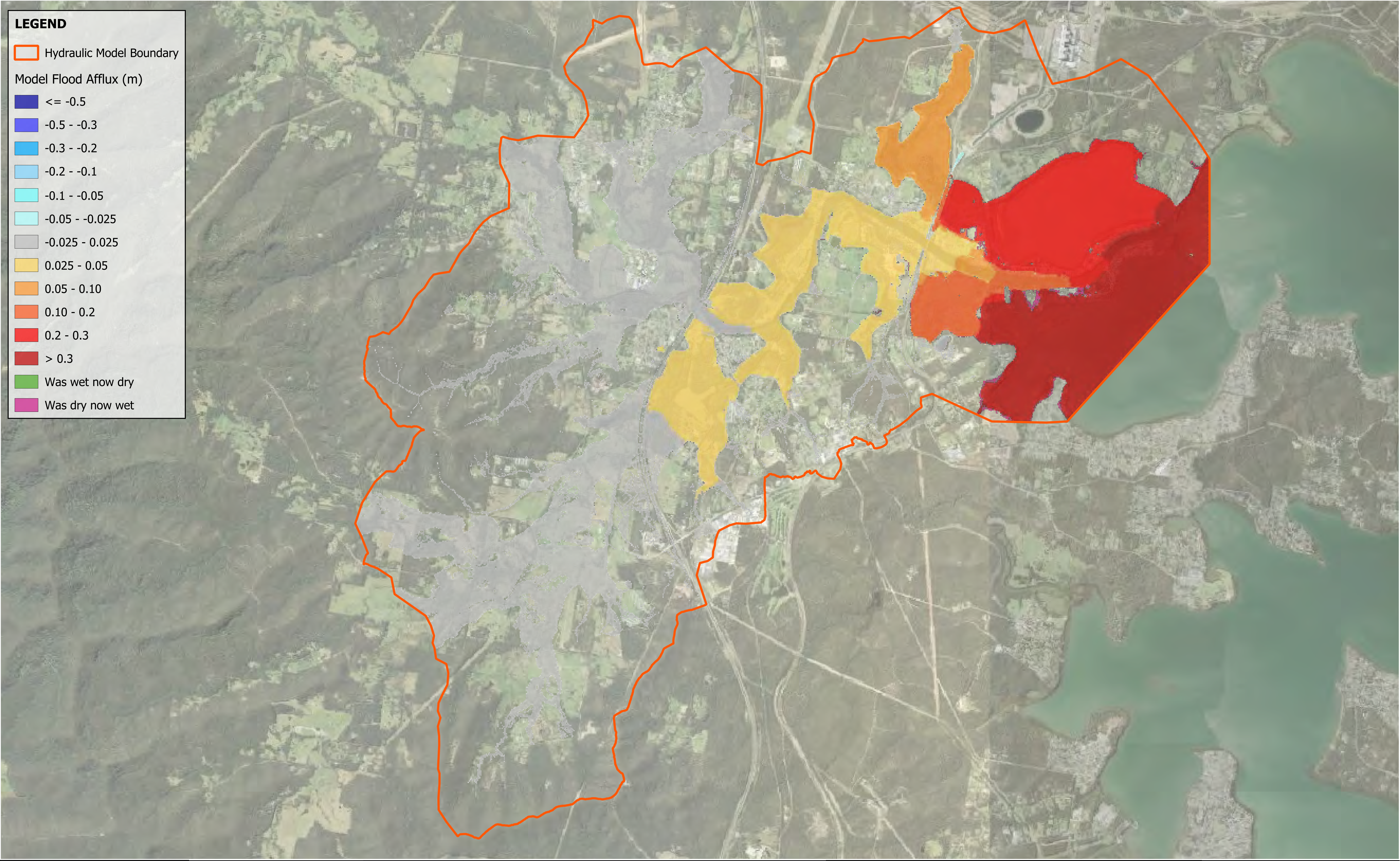
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.14: 1% AEP (100 Year ARI) - Climate Change

Sea Level Rise (0.5m) - Modelled Flood Velocity-Depth Product

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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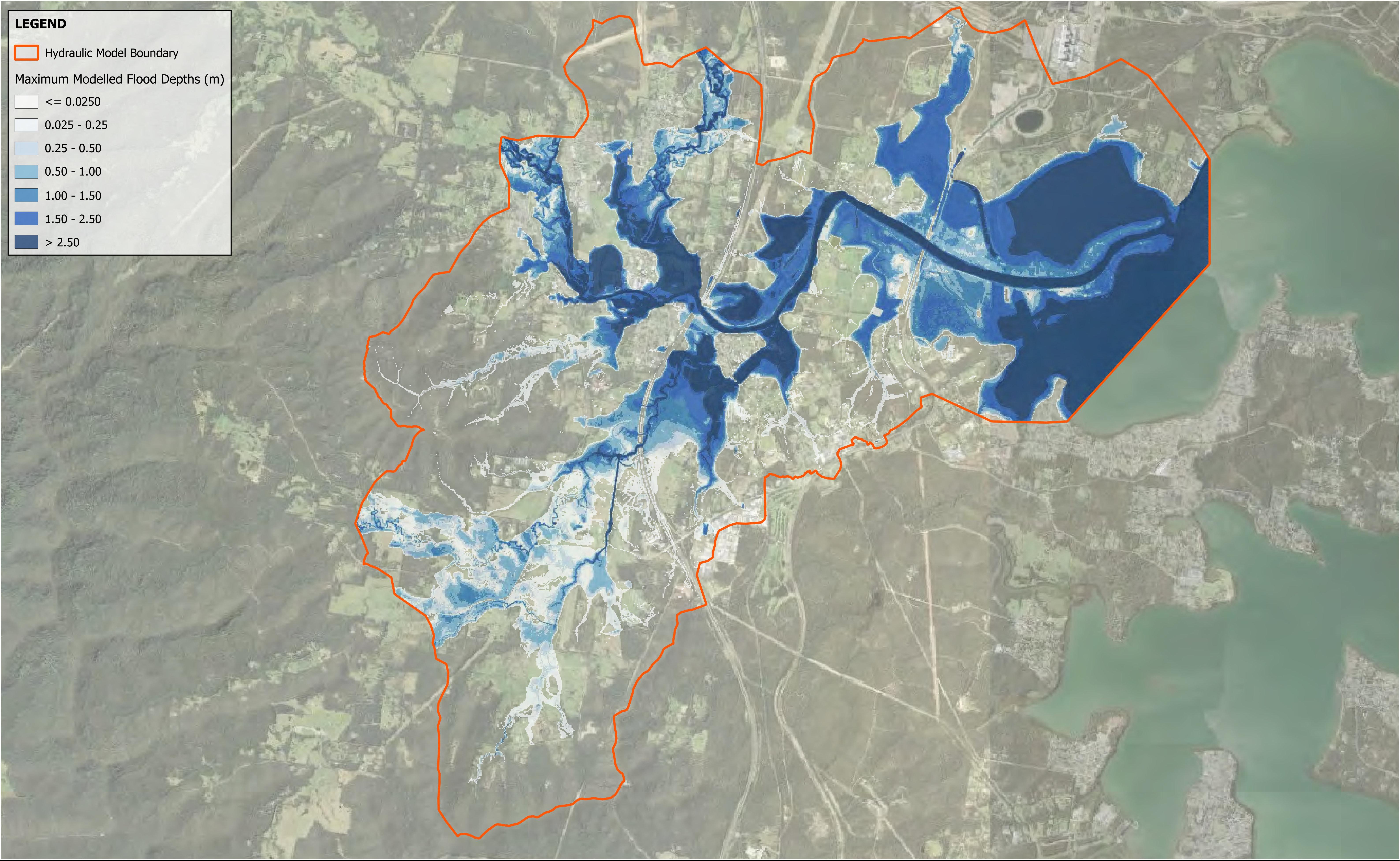
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.15: 1% AEP (100 Year ARI) - Climate Change

Modelled Flood Afflux (Basecase vs Sea Level Rise (0.5m))

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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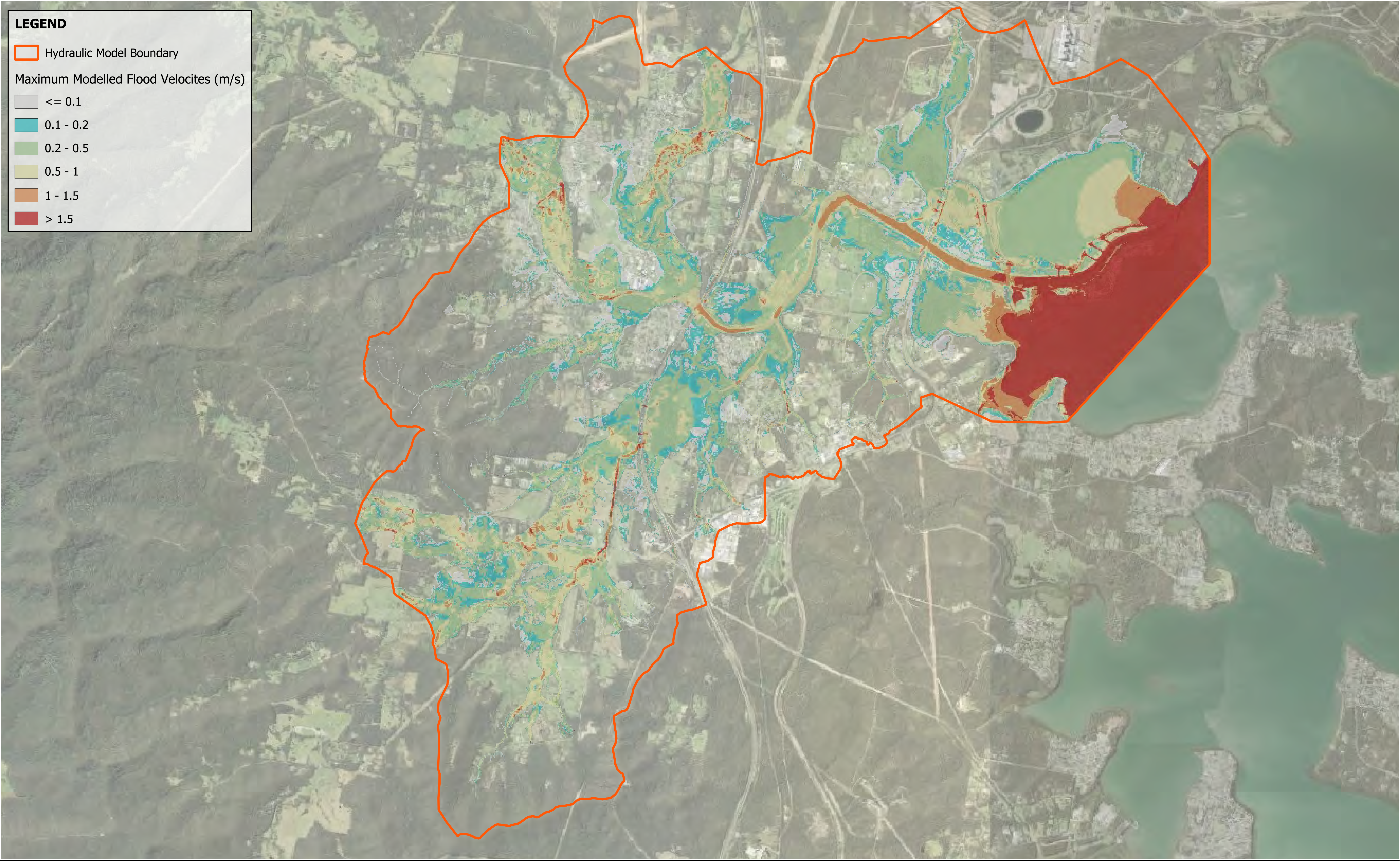
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.16: 1% AEP (100 Year ARI) - Climate Change

Sea Level Rise (0.9m) - Modelled Flood Depths

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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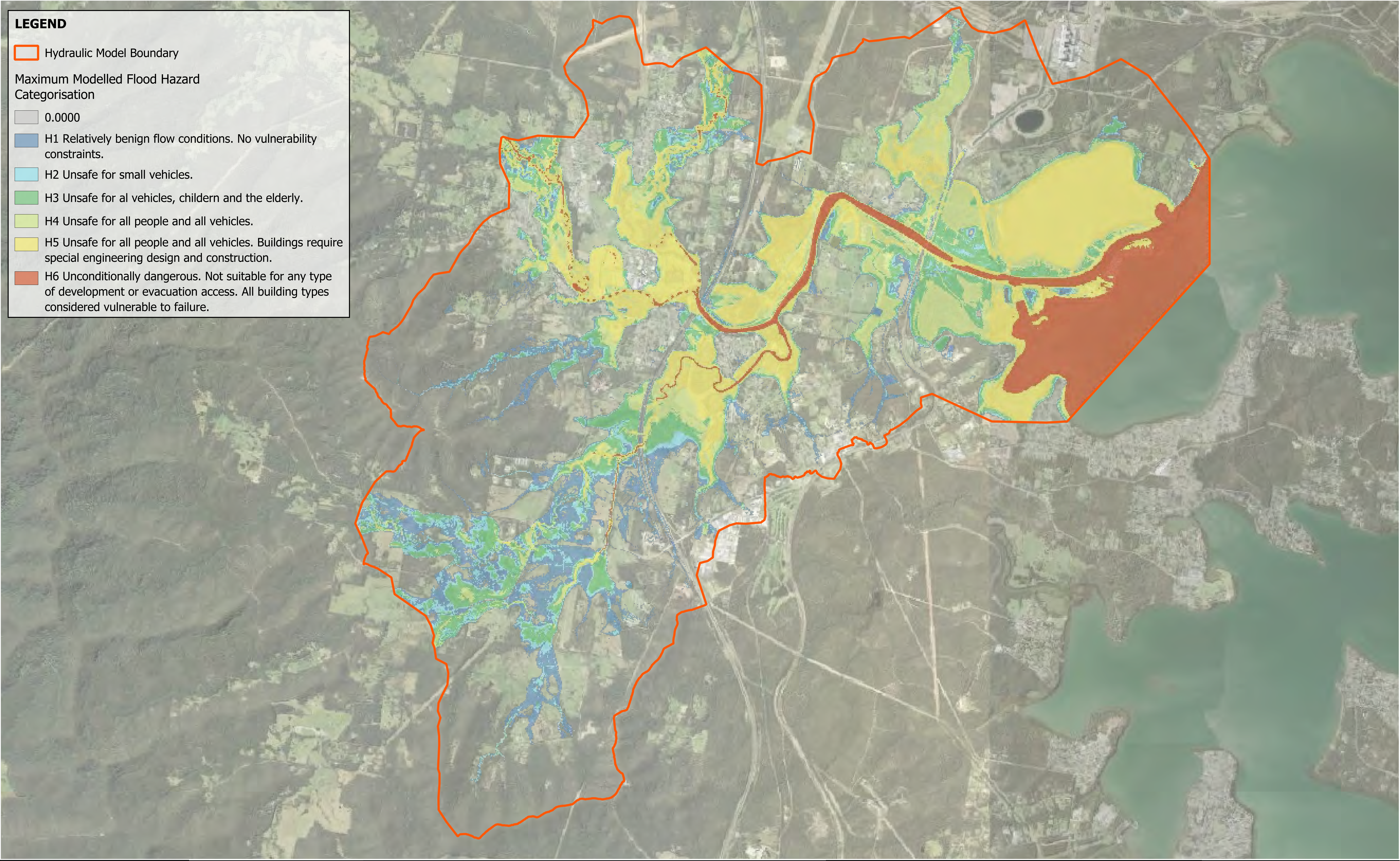
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.17: 1% AEP (100 Year ARI) - Climate Change

Sea Level Rise (0.9m) - Modelled Flood Velocity

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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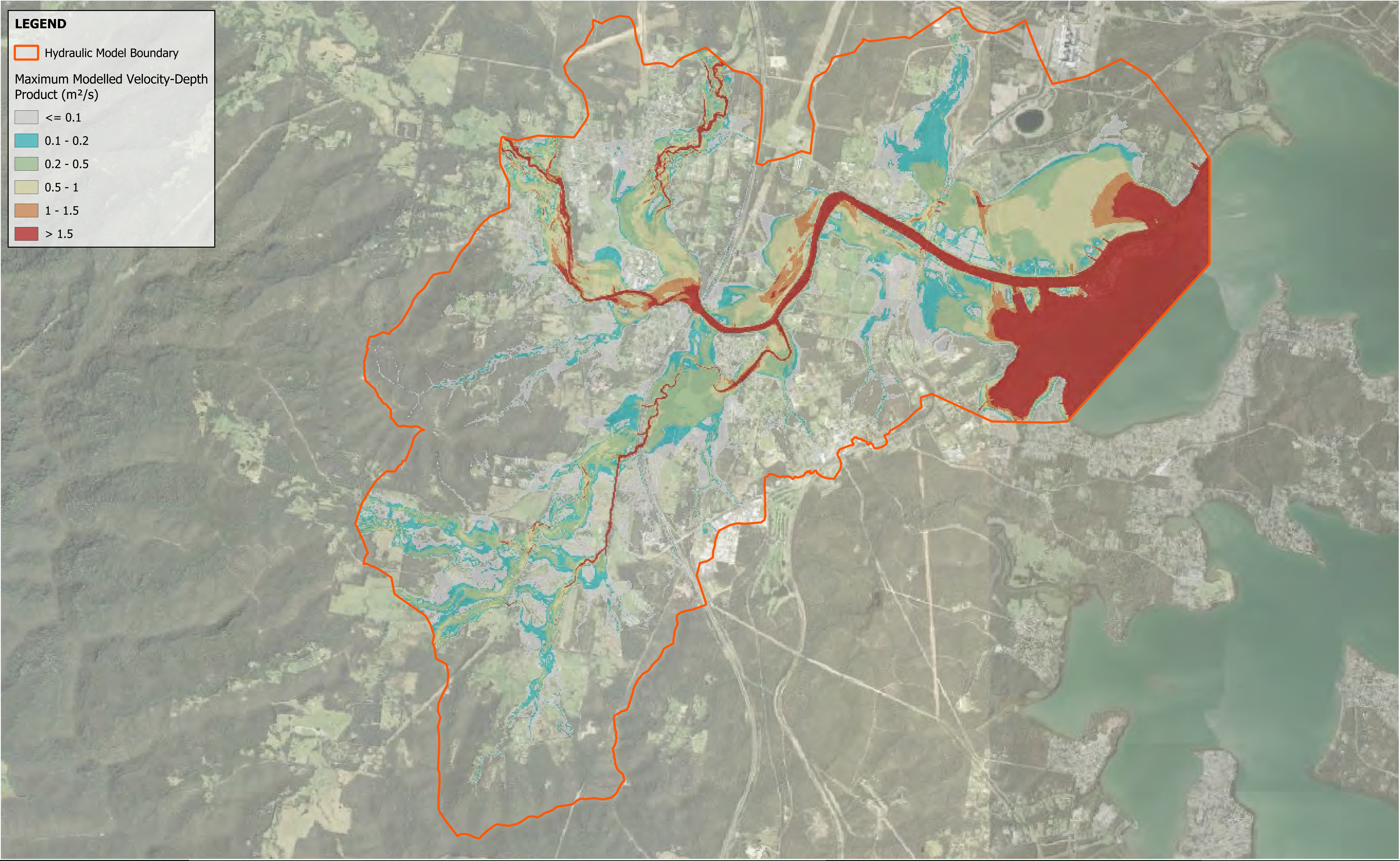
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.18: 1% AEP (100 Year ARI) - Climate Change

Sea Level Rise (0.9m) - Modelled Flood Hazard Categorisation

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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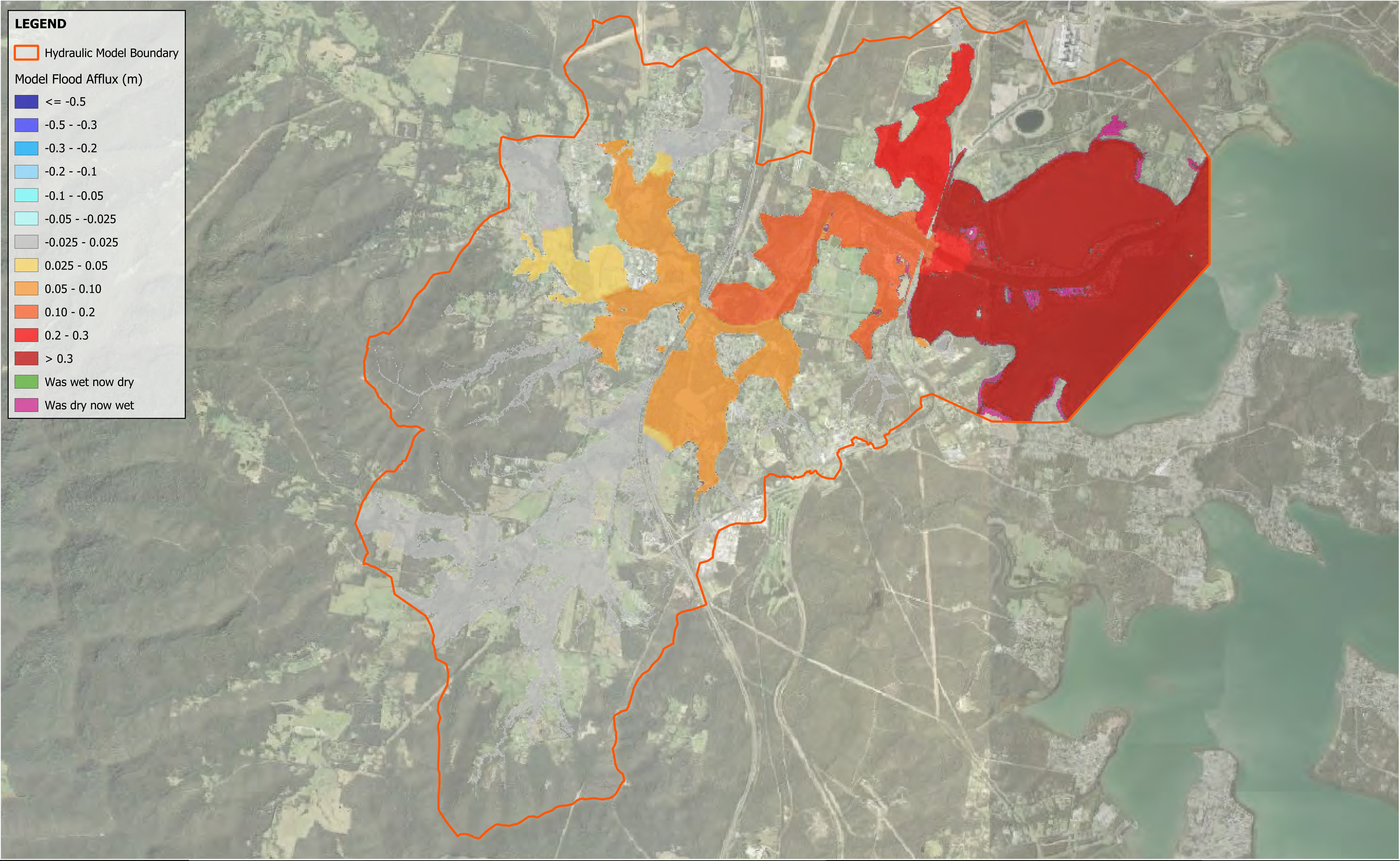
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.19: 1% AEP (100 Year ARI) - Climate Change
Sea Level Rise (0.9m) - Modelled Flood Velocity-Depth Product

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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Map Projection: Tranverse Mercator
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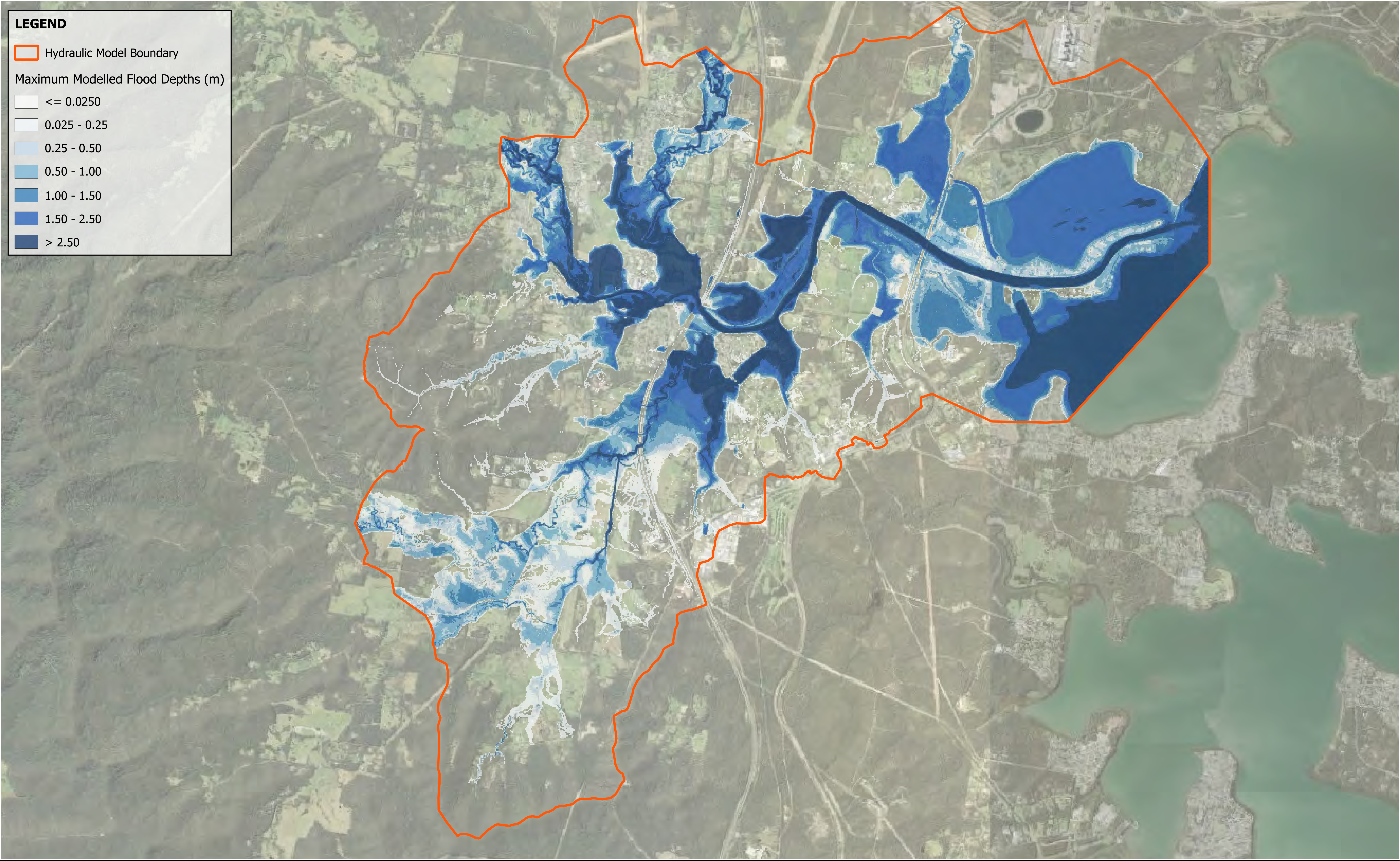
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.20: 1% AEP (100 Year ARI) - Climate Change
Modelled Flood Afflux (Basecase vs Sea Level Rise (0.9m))

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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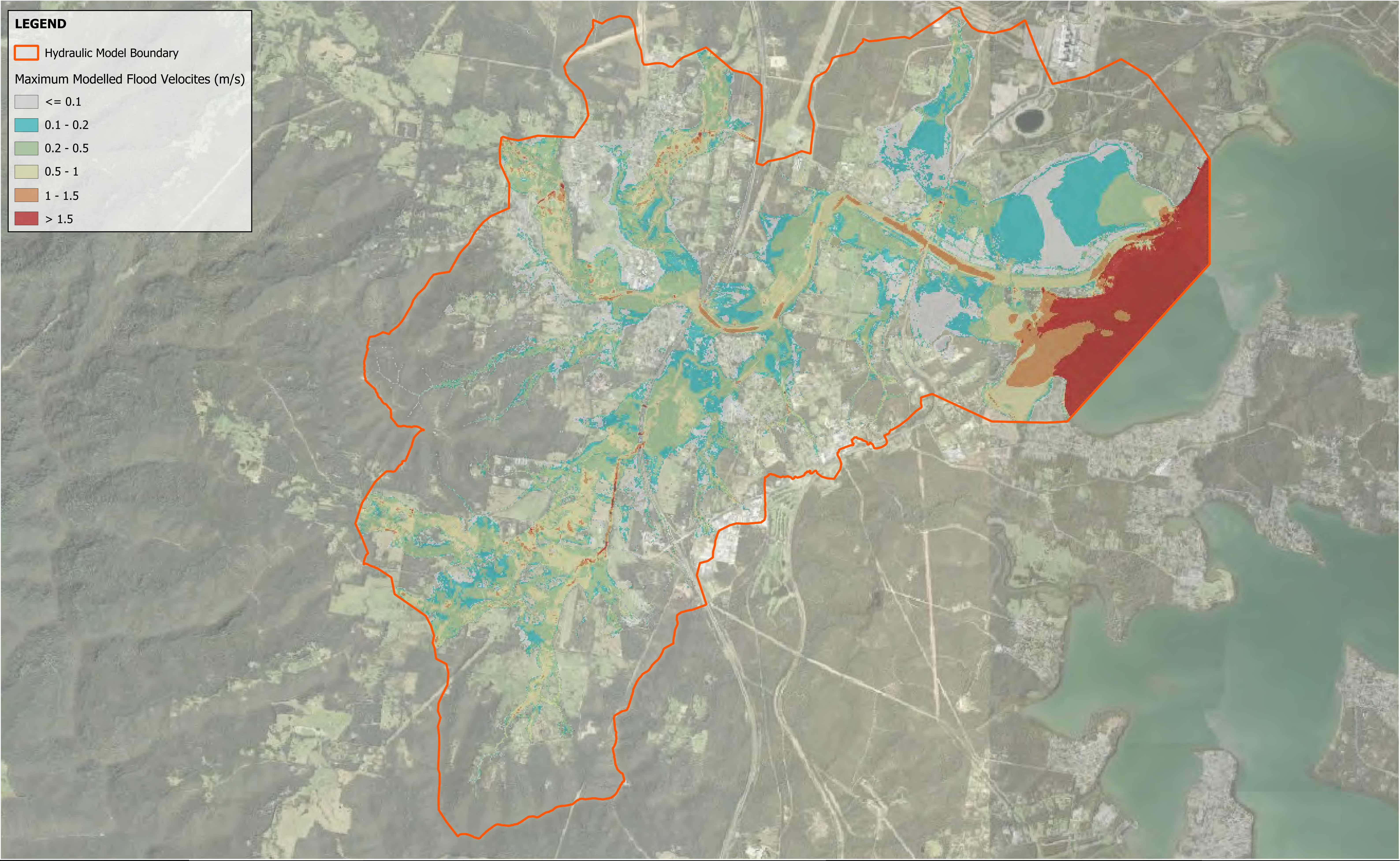
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.21: 1% AEP (100 Year ARI) - Mannings Roughness
Increased Mannings Roughness (25%) - Modelled Flood Depths

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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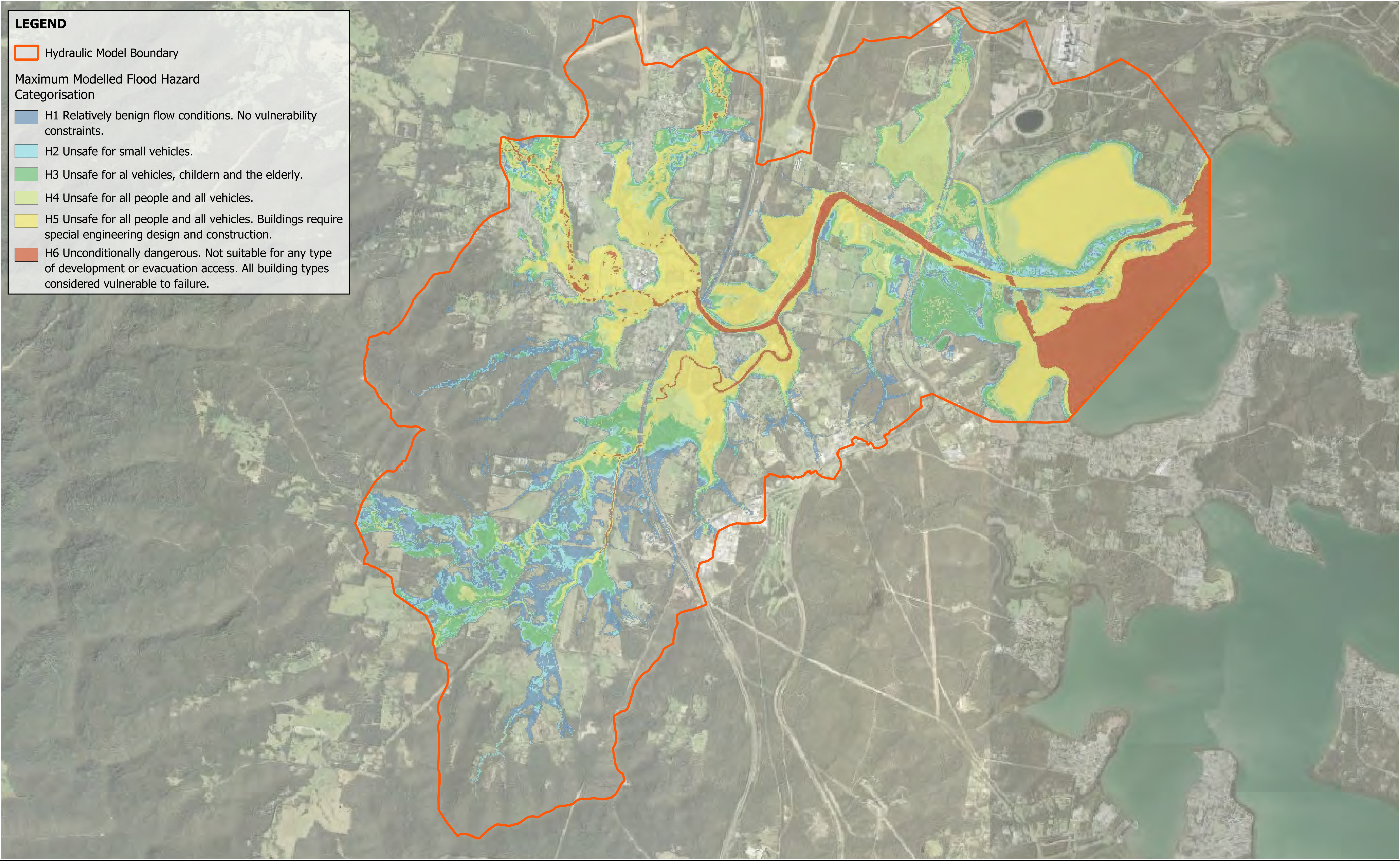
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.22: 1% AEP (100 Year ARI) - Mannings Roughness

Increased Mannings Roughness (25%) - Modelled Flood Velocity

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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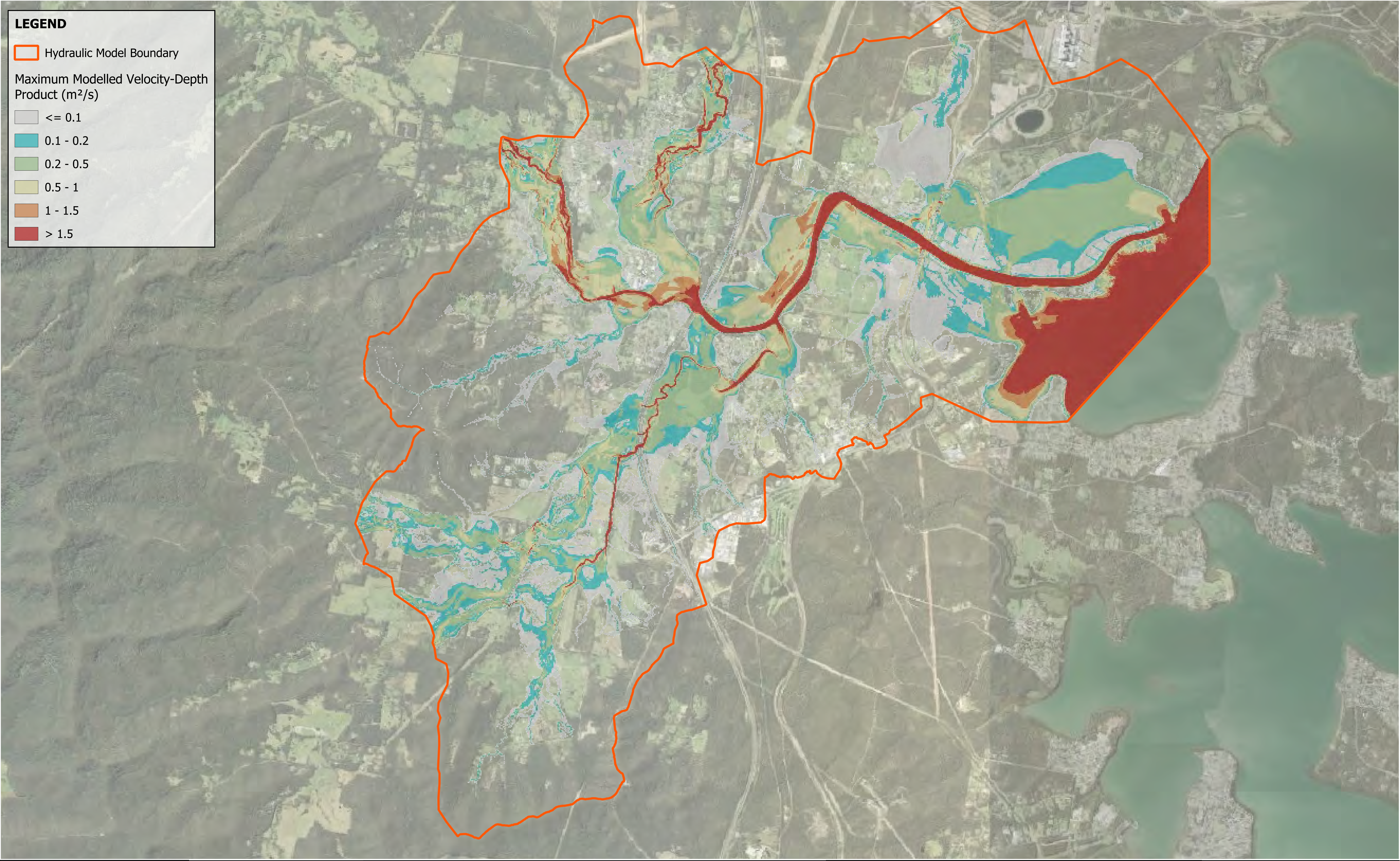
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.23: 1% AEP (100 Year ARI) - Mannings Roughness

Increased Mannings Roughness (25%) - Modelled Flood Hazard Categorisation

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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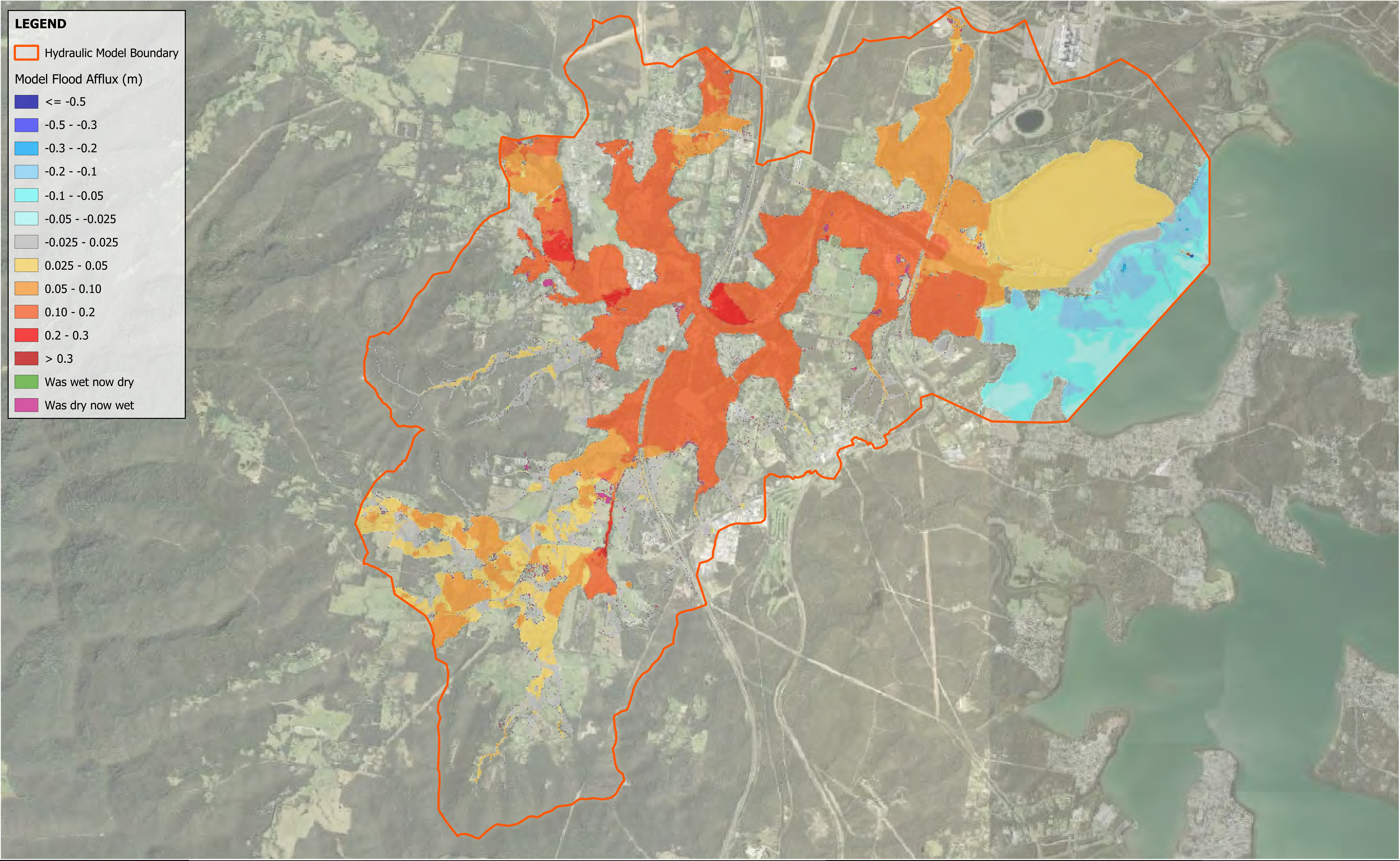
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.24: 1% AEP (100 Year ARI) - Mannings Roughness

Increased Mannings Roughness (25%) - Modelled Flood Velocity- Depth Product

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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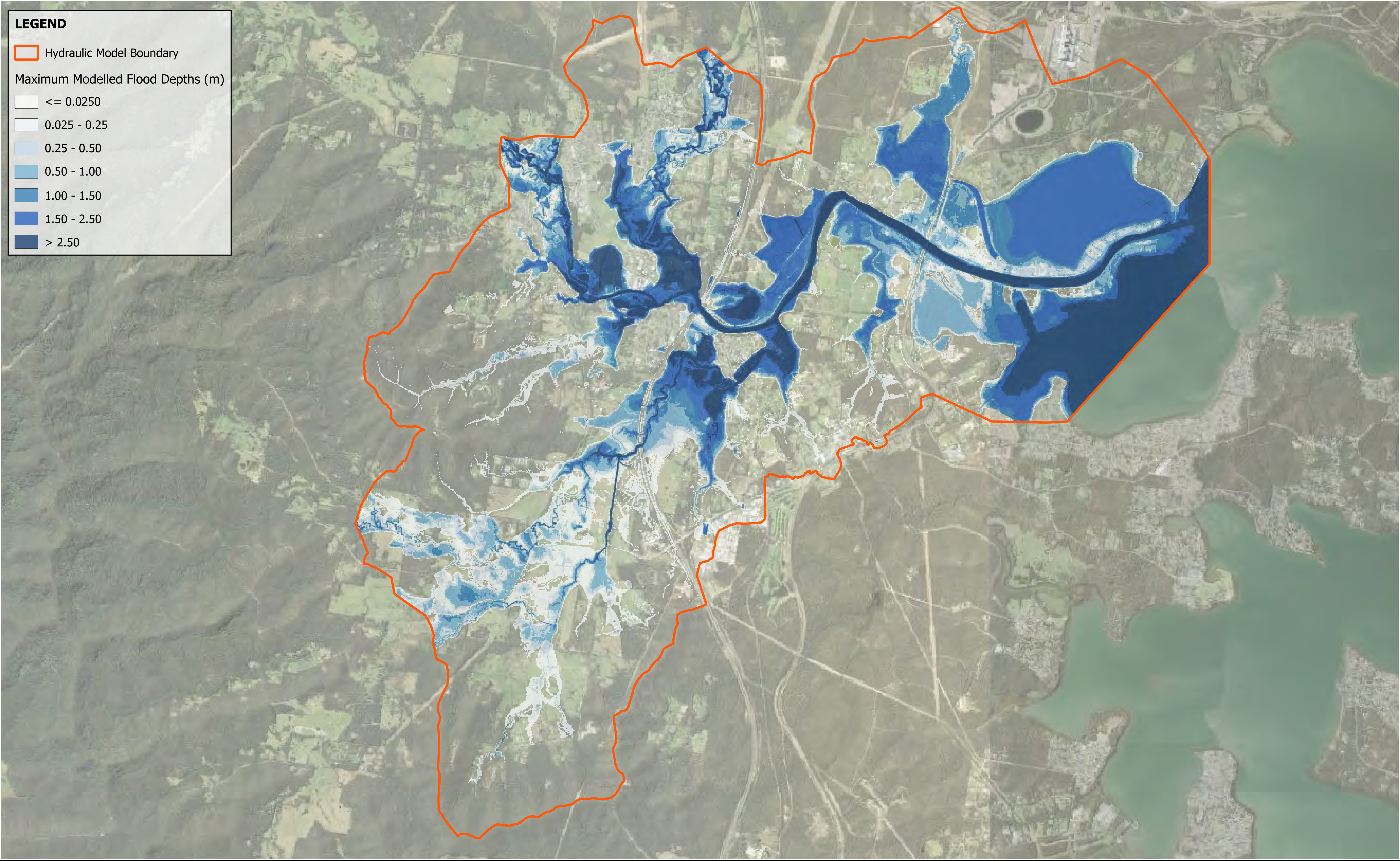
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.25: 1% AEP (100 Year ARI) - Mannings Roughness

Modelled Flood Afflux (Basecase vs 25% Mannings Roughness Increase)

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
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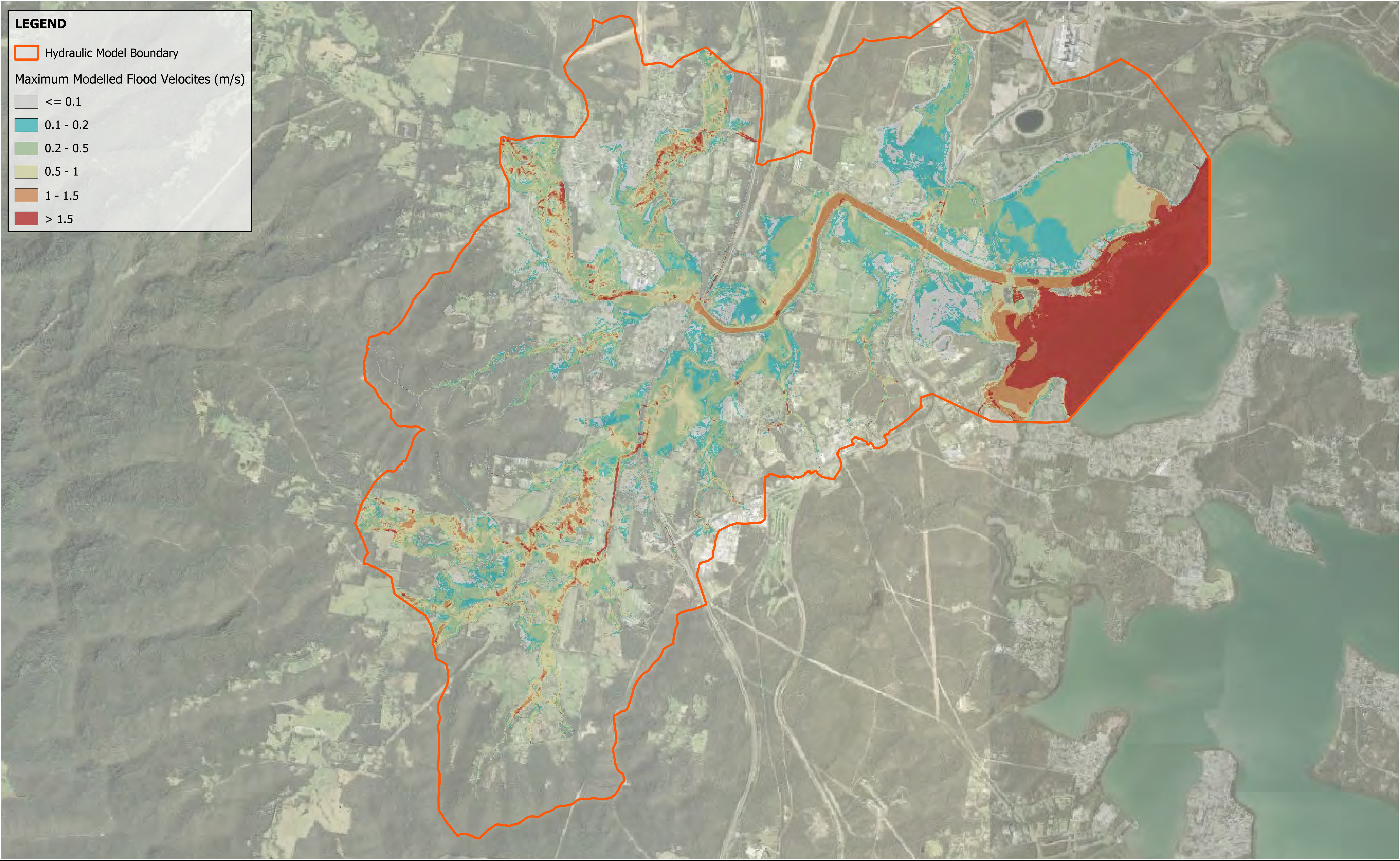
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.26: 1% AEP (100 Year ARI) - Mannings Roughness
Decreased Mannings Roughness (25%) - Modelled Flood Depths

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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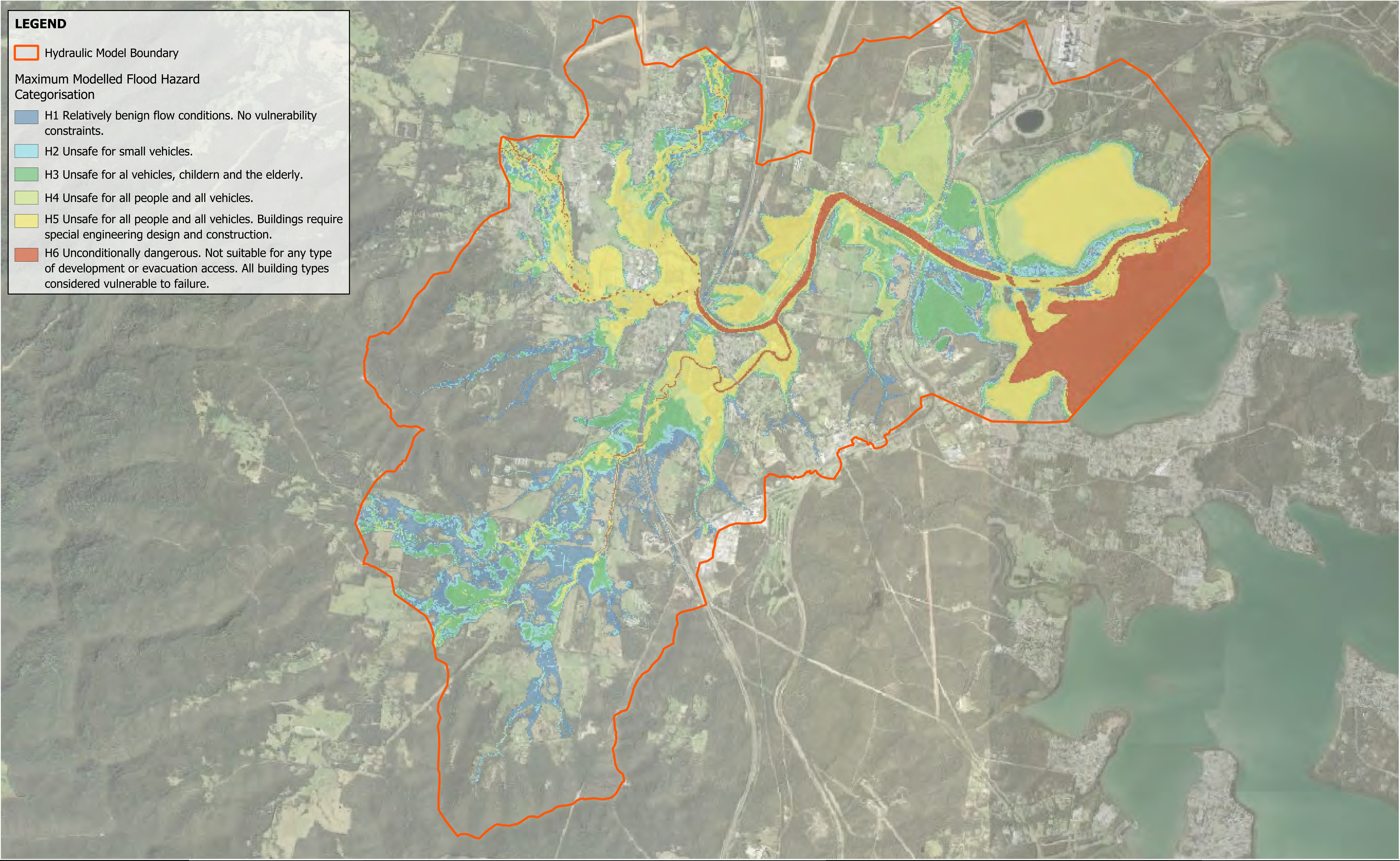
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.27: 1% AEP (100 Year ARI) - Mannings Roughness
Decreased Mannings Roughness (25%) - Modelled Flood Velocity

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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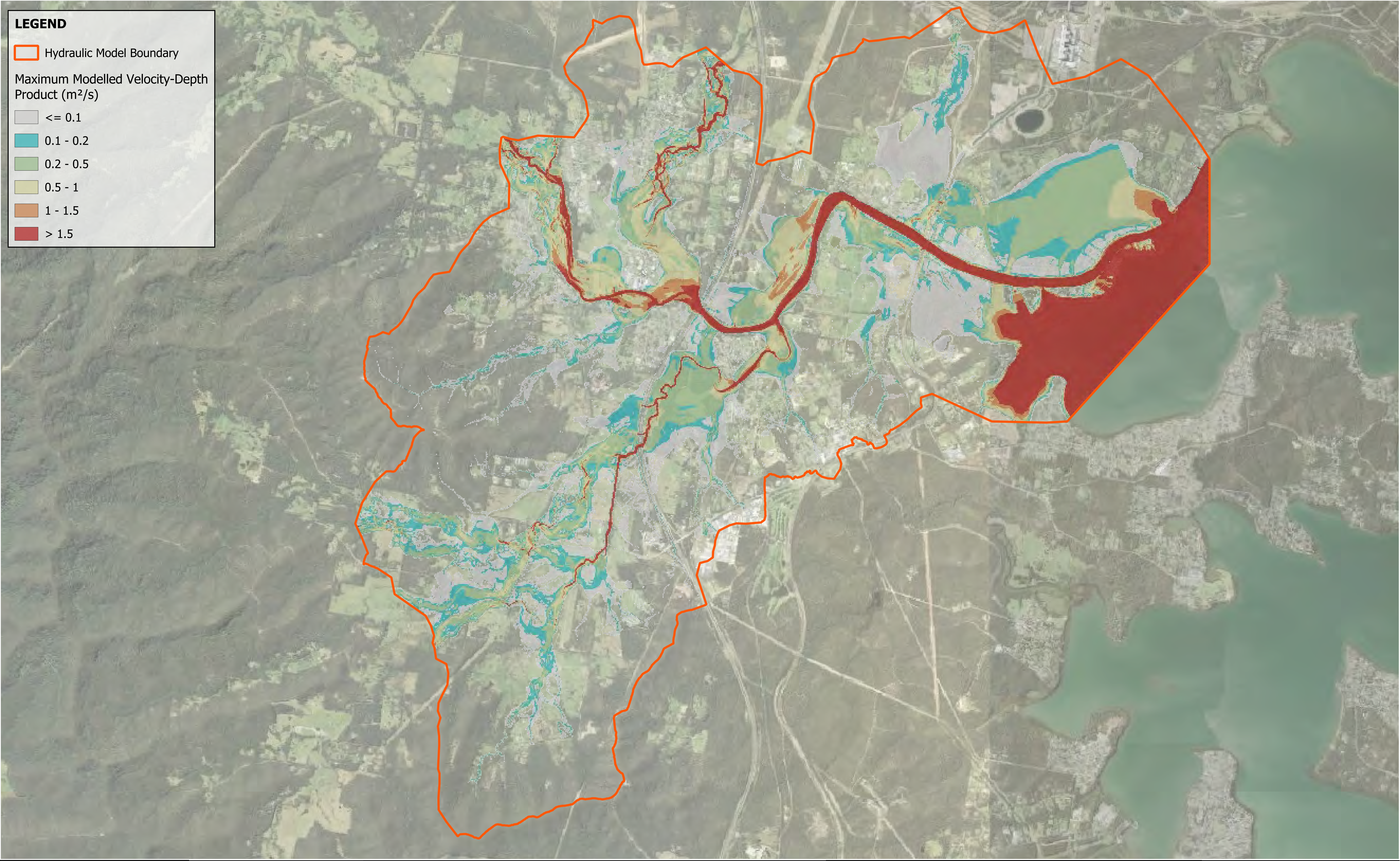
Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.28: 1% AEP (100 Year ARI) - Mannings Roughness

Decreased Mannings Roughness (25%) - Modelled Flood Hazard Categorisation

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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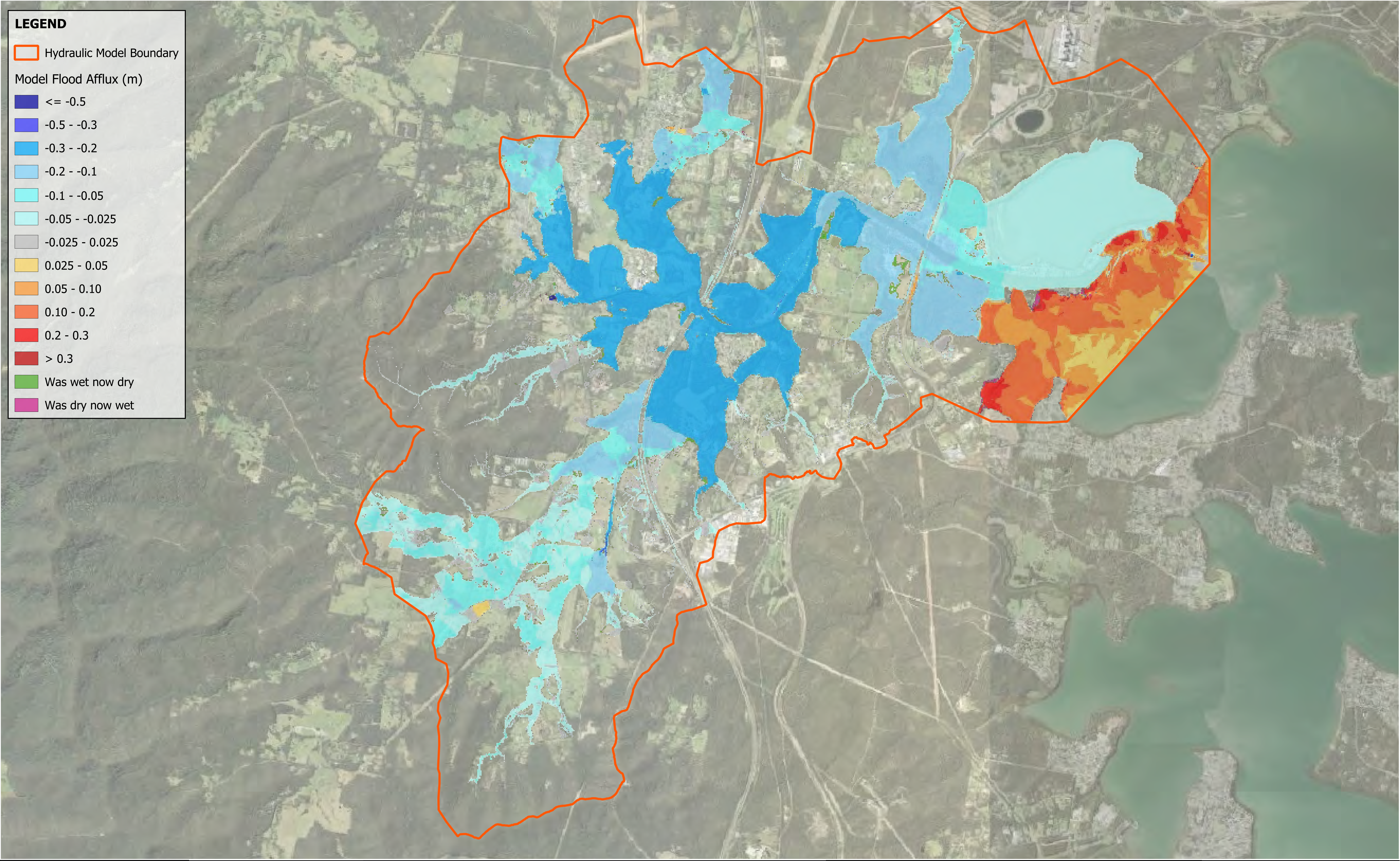
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.29: 1% AEP (100 Year ARI) - Mannings Roughness
Decreased Mannings Roughness (25%) - Modelled Flood Velocity- Depth Product

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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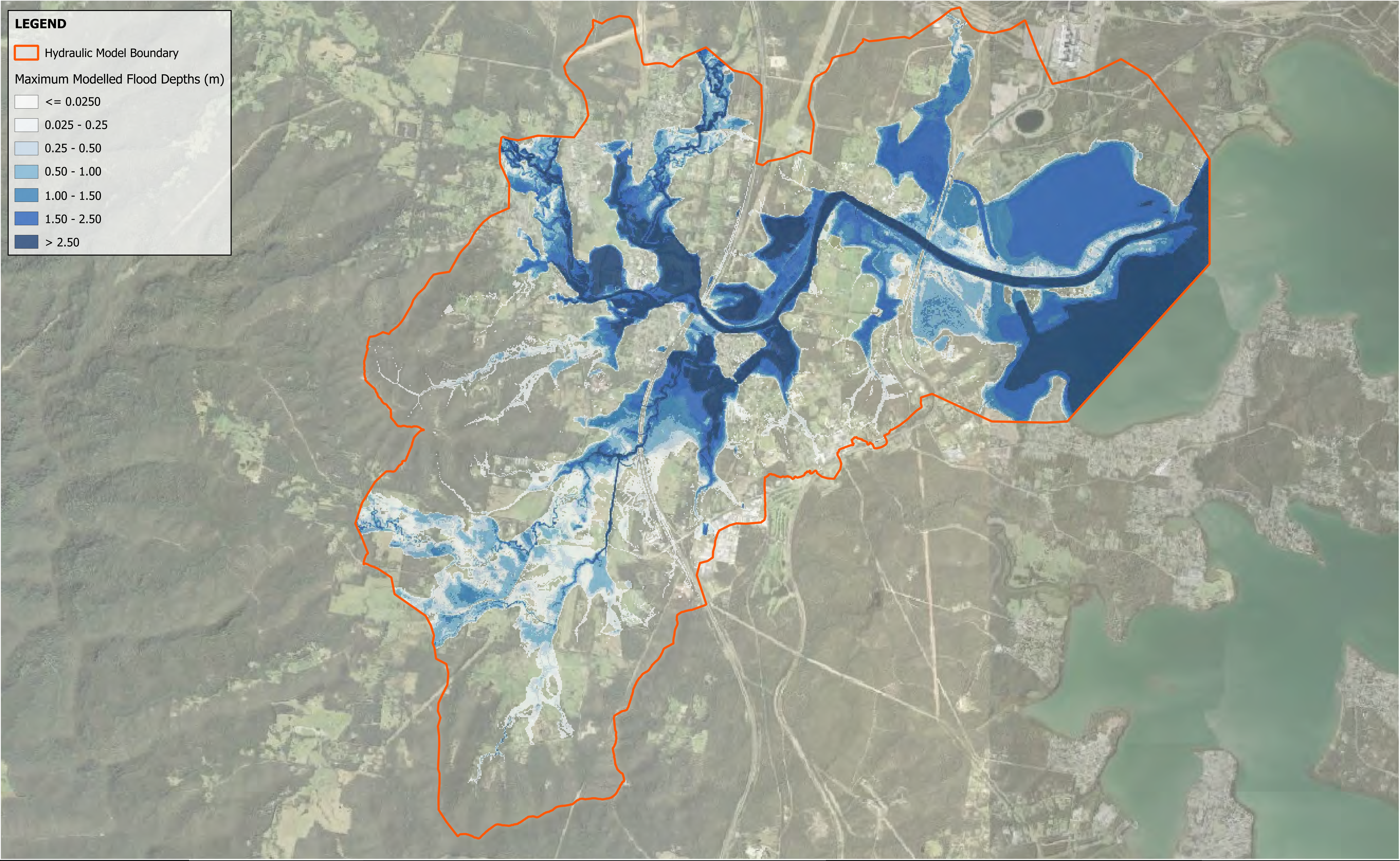
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.30: 1% AEP (100 Year ARI) - Mannings Roughness

Modelled Flood Afflux (Basecase vs 25% Mannings Roughness Decrease)

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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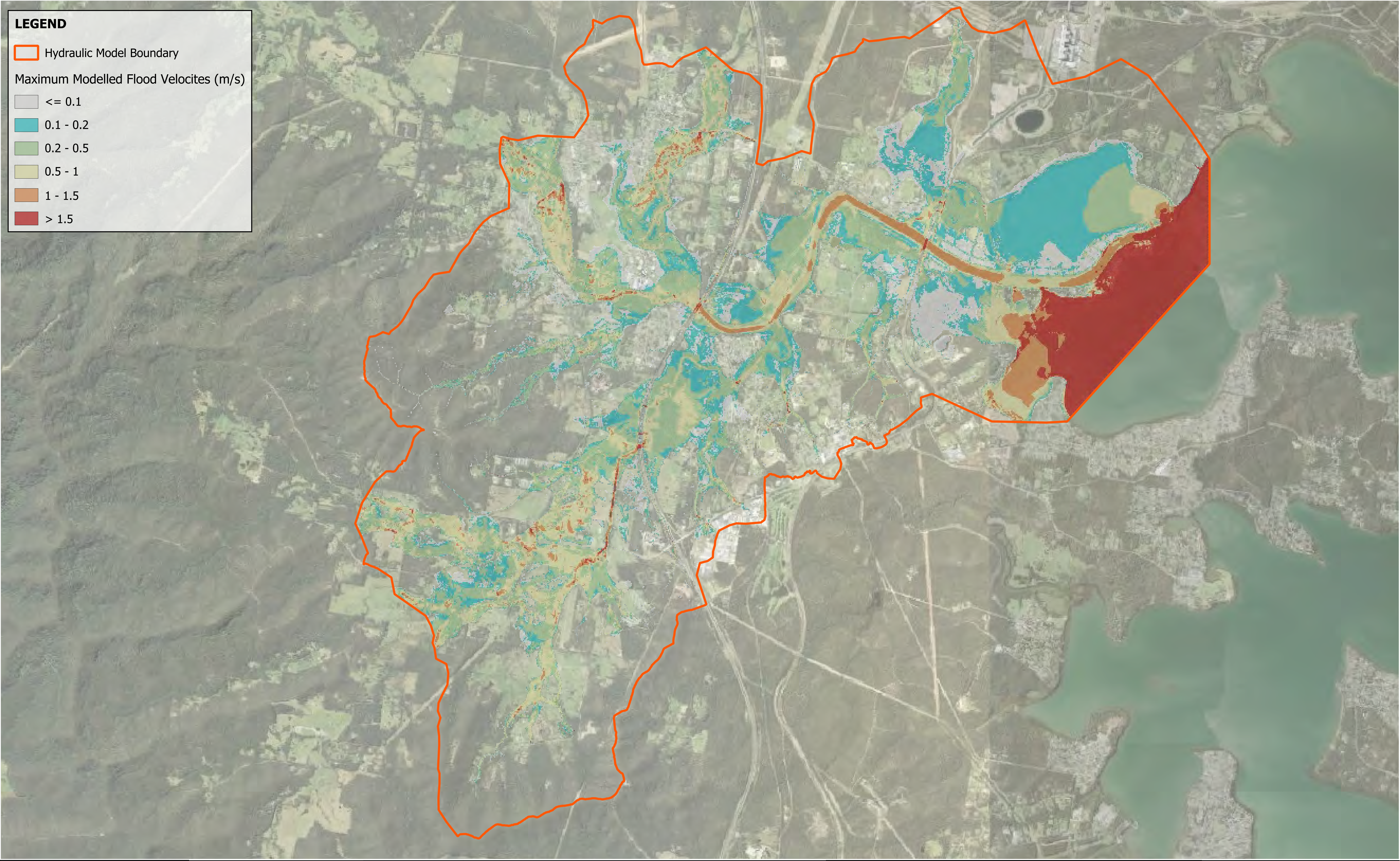
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.31: 1% AEP (100 Year ARI) - Blockage

Modelled Flood Depths

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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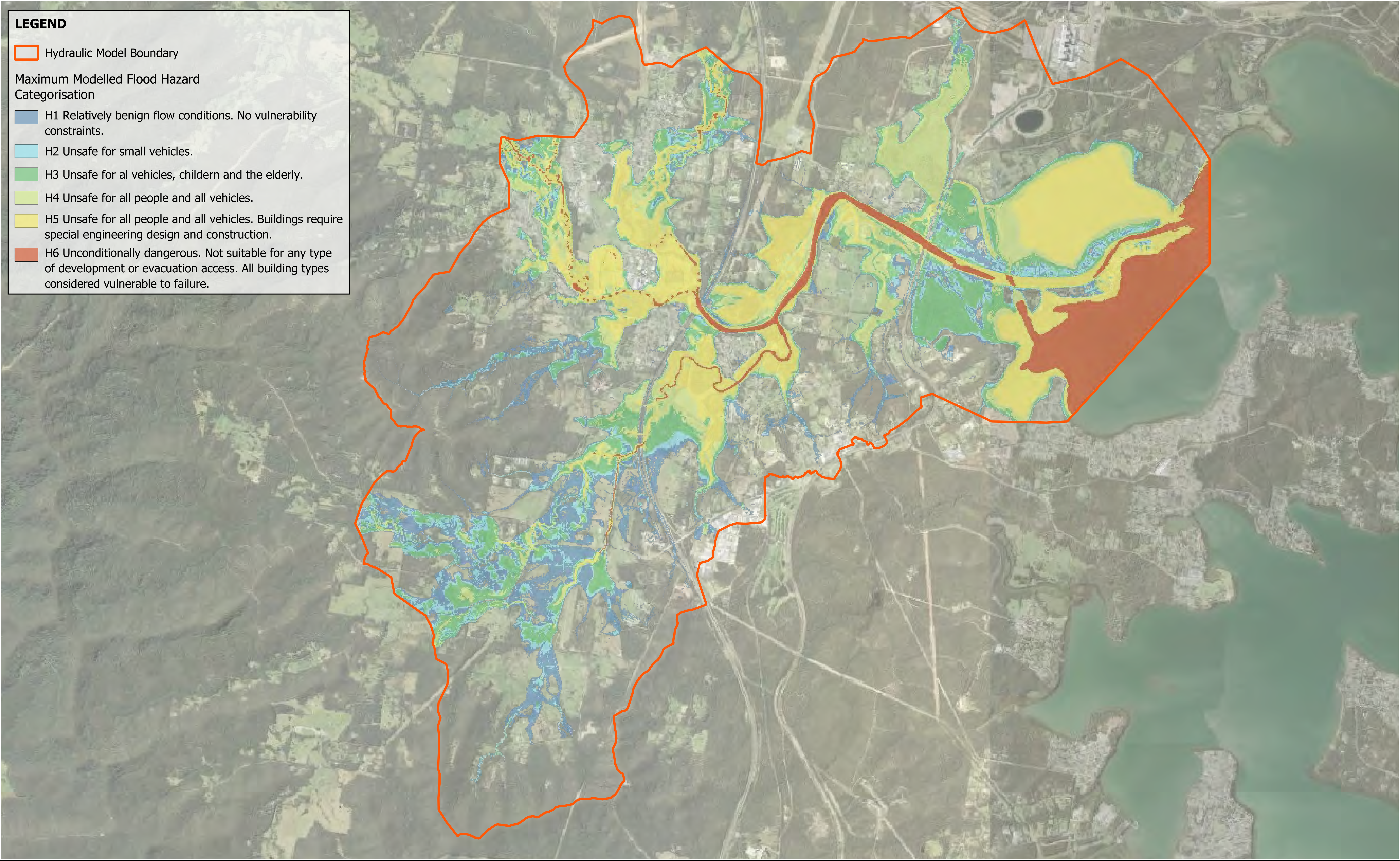
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.32: 1% AEP (100 Year ARI) - Blockage

Modelled Flood Velocity

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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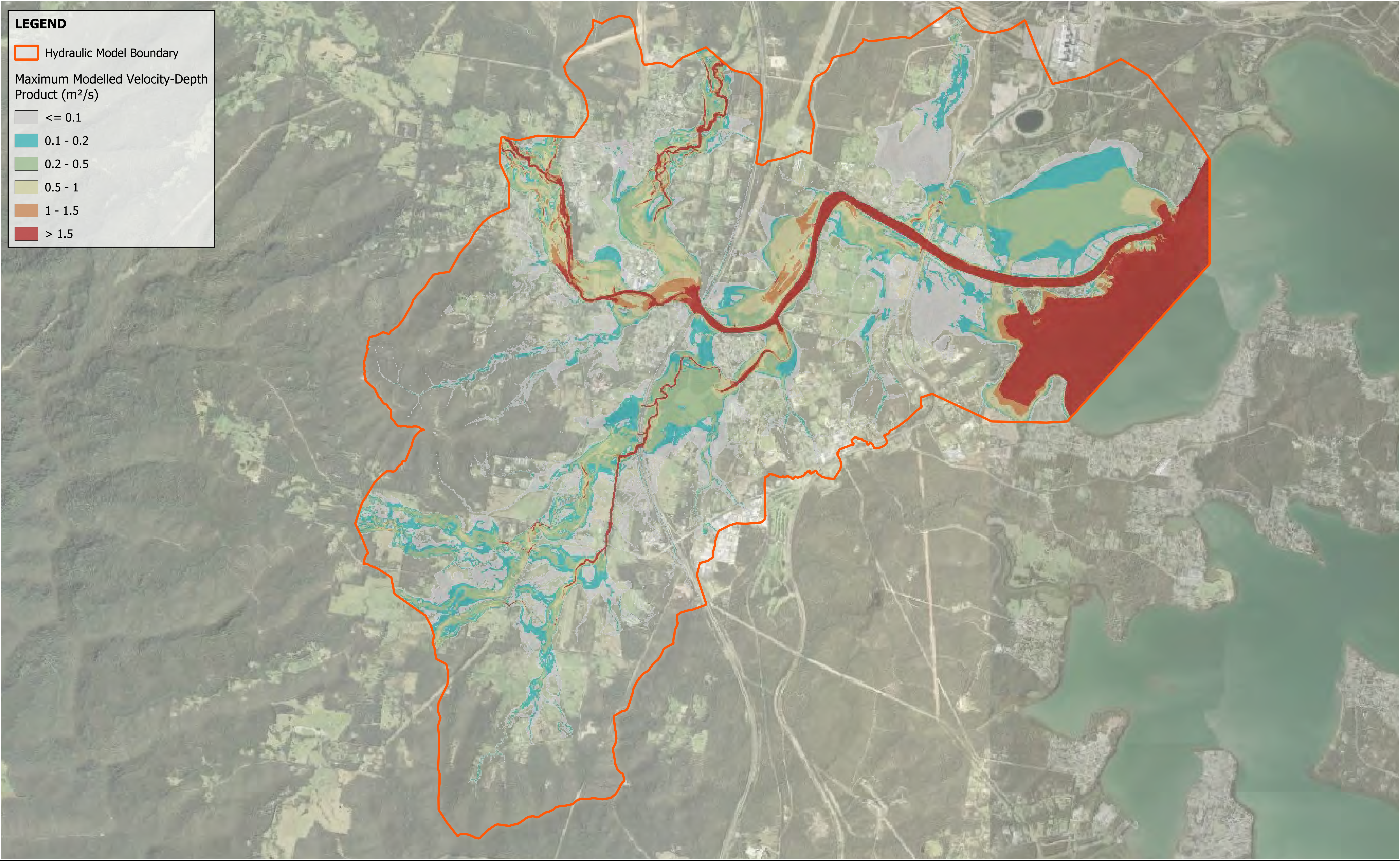
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.33: 1% AEP (100 Year ARI) - Blockage

Modelled Flood Hazard Categorisation

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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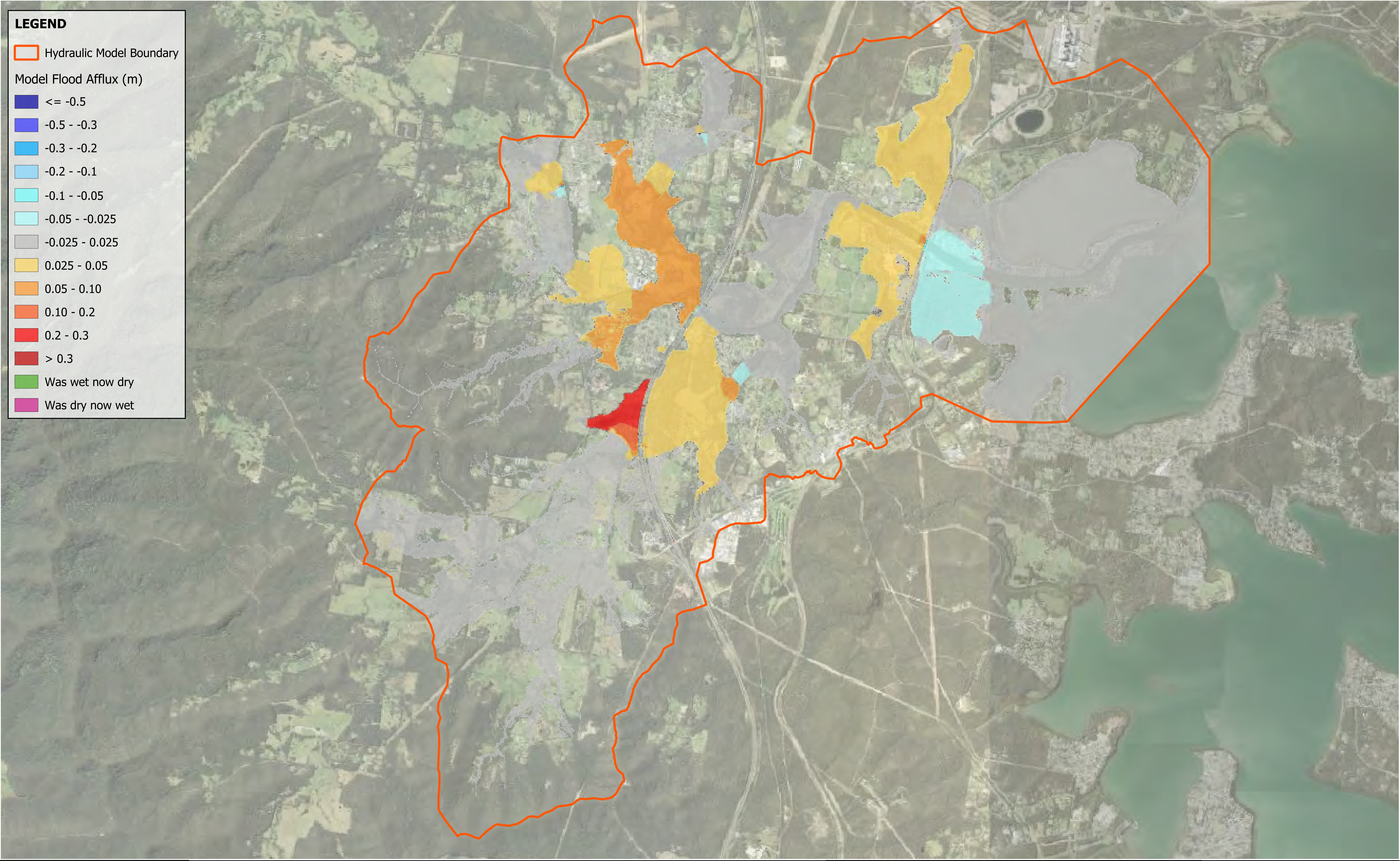
Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.34: 1% AEP (100 Year ARI) - Blockage

Modelled Flood Velocity- Depth Product

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024



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Scale in metres (1:42,500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Figure C.35: 1% AEP (100 Year ARI) - Blockage

Modelled Flood Afflux (Basecase (unblocked) vs Blocked)

Job Number: NC2006_001
Revision: 0
Drawn: IR
Checked: MB
Date: 31/7/2024